2008

Harbor seal behavioral reponse to boaters at Bair Island refuge

Kathlyn Snyder Fox
San Jose State University

HARBOR SEAL BEHAVIORAL RESPONSE TO BOATERS

AT BAIR ISLAND REFUGE

A Thesis

Presented to

The Faculty of the Department of Environmental Studies

San Jose State University

In Partial fulfillment

of the Requirements for the Degree

Master of Science

by

Kathlyn Snyder Fox

December 2008

SAN JOSE STATE UNIVERSITY

The Undersigned Thesis Committee Approves the Thesis Titled

HARBOR SEAL BEHAVIORAL RESPONSE TO BOATERS

AT BAIR ISLAND RESERVE

by
Kathyn Snyder Fox

APPROVED FOR THE DEPARTMENT OF ENVIRONMENTAL STUDIES

Lynne Trulio 12/11/08
Dr. Lynne Trulio, Department of Environmental Studies Date

Rachel T. O'Malley 11/12/08
Dr. Rachel O'Malley, Department of Environmental Studies Date

12/11/08
Clyde Morris, United States Fish and Wildlife Service Date

APPROVED FOR THE UNIVERSITY

David K Bruck 1/23/09
Associate Dean Office of Graduate Studies and Research Date

ABSTRACT

HARBOR SEAL BEHAVIORAL RESPONSE TO BOATERS AT BAIR ISLAND REFUGE

by Kathlyn Snyder Fox

Harbor seals *(Phoca Vitulina Richardsi)* that haul out on the banks of Corkscrew Slough within Bair Island Refuge, San Mateo County, California encounter a variety of boats along the waterway. This study documented numbers of seals and boats using Corkscrew Slough and examined seals' behavioral responses to boats. Seal counts were also obtained at Outer Bair Island, where boats are rare.

Maximum counts of 50-60 seals were obtained during pupping-molting season. Seals and boaters were present year round, but seals encountered boats less than 1% of the time observed. Motorized boats represented 49% of traffic and non-motorized 40%. Non-motorized boats caused 55% of flush responses.

While seal vigilance increased as boats passed the haul out, seals relaxed within 10 minutes of boats' disappearance. On days with multiple boats, the number of seals was significantly fewer than on days with no boats. Seal vigilance increased as boats came closer to seals.

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation for my thesis committee members who guided me through all phases of this project. Dr. Lynne Trulio, my committee chair, adviser, and first professor at San Jose State University, has inspired me with her passion for wildlife, her commitment to improving the environment, and her leadership by example. Her depth of knowledge in field research, enthusiasm, and support were essential. Dr. Rachel O'Malley's insights with respect to study design and statistics have strengthened my research skills. Clyde Morris, Manager of Don Edwards National Wildlife Refuge, made this project possible with his knowledge and interest.

Many thanks go to my intrepid field assistants Phil Higgins, from Ireland, and Clement Guyot, from France. Their love of nature, "can –do" attitudes, sense of humor, and their willingness to spend hours getting dirty, wet, and cold, in order to observe the daily lives of harbor seals will endear them to me always.

I appreciate Dr. Katherine Cushing for her inputs and encouragement and Emma Grigg, Diane Kopec, and Norton Bell for sharing their knowledge about seals. The funds from a 2006 SJSU College of Social Sciences Grant were very helpful to my project.

Love and special thanks go to my husband Chuck Fox, who bought and repaired my boat and always kept it afloat, helped in the field and on the computer, and who always kept his faith in me. Finally, I thank my mother and father who nurtured my love for animals, instilled my passion for learning, and encouraged me to follow my dreams.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

The ability of human beings and wildlife to coexist in natural habitats is fundamental to the success of parks and reserves that have been established for the dual purposes of wildlife protection and public outdoor recreation. As our society becomes increasingly urbanized, trends show a growing popularity for activities such as hiking, boating, bird-watching, nature photography, eco-tourism, and wildlife viewing that bring people ever closer to wildlife in their natural habitat (Trulio, 2005; Cordell, Teasley, Super, Bergstrom, and McDonald, 1997). The benefits of public interest in nature include increased political support for the preservation of wild areas and a willingness to pay for parks, refuges, and open space areas that protect wildlife and habitat. Nevertheless, well intended and supportive as outdoor enthusiasts may be, numerous studies have shown that humans frequently disturb wildlife they encounter in natural settings, often to the degree that species survival and breeding success are threatened (Gill, Sutherland, and Watkinson, 2001; Boyle and Samson, 1985; Carney and Sydeman 1999; Lafferty, Goodman, and Sandoval 2006).

Public access represents one of the major challenges today's wildlife managers face with respect to protecting species and habitat; that is how to maintain the appropriate balance between allowing the public to experience and enjoy these valuable resources while also preventing the negative impacts of disturbance and destruction, which often accompany human activity in natural settings. Solutions to this challenge can benefit by emphasizing two different, yet complementary, approaches to the problem. First, efforts must be made to better understand wildlife responses to recreational activity, and second, efforts can be made to manage both species and people in order to prevent significant species impacts.

Currently, the tools and knowledge for minimizing the impact of human disturbance to wildlife are lacking, leaving wildlife managers guessing with respect to how much human interaction various animal and bird species can tolerate before they will begin to suffer stress, loss of offspring, habitat abandonment, and potentially, death. While numerous studies describe and quantify disturbance, management recommendations are more limited, consisting largely of restricting human access or creating protective buffer zones. For example, Orams (2002) discusses the tradeoffs involved with feeding wildlife in the wild and points to the lack of empirical research that could assist management efforts in this regard. Frid and Dill (2002) describe the lack of a solid theoretical framework for quantifying and predicting animal response to non-lethal human disturbances and recommend wide application of predation risk theory to the topic. Reynolds and Braithwaite (2001) present a new conceptual framework for analyzing the major components of wildlife tourism and discuss possible mechanisms for making such tourism sustainable.

Related Research

Human Disturbance of Wildlife

Human disturbance of wildlife has been documented for a wide variety of species including waterfowl, shorebirds, wading birds and raptors, moose, bighorn sheep, small mammals, and marine mammals (Andersen, 1996; Belanger, 1989; Pfister, 1992; Stockwell et al., 1991; Gill, 2001; Allen, 1984) in numerous situations and habitats. Wildlife can be disturbed by hikers, joggers, campers, bicyclists, and especially photographers, who often approach animals or birds directly and closely (Klein, 1993). Motorized vehicles including snowmobiles, personal watercraft and ATVs are able to access remote, rugged areas that were previously inaccessible for the most part. Increased watercraft activities such as kayaking, canoeing and motor-boating leave fewer shoreline areas undisturbed and available to wildlife for respite, relaxation, and care of their young.

Numerous studies have characterized human disturbance to wildlife. Knight and Cole (1995) identify two broad categories of disturbance; consumptive, including hunting, fishing and some types of research, and non-consumptive, including wildlife viewing, hiking, boating and other types of research. Non- consumptive recreation involves observing wildlife in a natural setting without directly harming or capturing the animal. In these cases humans are often unaware of the impact they are having on wildlife as they pursue their recreational activities. Consumptive recreation involves intentional killing of individuals, but can also impact survivors by causing flight behavior, redistributing animals who avoid hunted areas (Madsen and Fox, 1995), and impacting offspring who will not survive after the death of a parent.

The negative impacts of disturbance range from direct effects such as nest abandonment, loss of eggs and chicks, increased stress resulting in physiological depletion and even death, to indirect effects such as destruction of native vegetation, attraction of predators and reduction in fecundity (Knight and Cole, 1995; Cole and Landres, 1995).

Various factors influence the degree to which disturbance from recreational activities harm wildlife. Effects are usually measured in terms of changes in behavior in response to human presence (Gill, Norris, and Sutherland, 2001). Some activities will cause severe disruption while others may have minimal effect (Knight and Cole, 1995). Knight and Cole (1995) highlight six variables that affect the way wildlife respond to disturbance including disturbance type, recreationist behavior, predictability, frequency and magnitude, and timing and location.

Types of recreation that have been found to produce significant disturbance include close range photography and wildlife viewing, while trail use by walkers and joggers can have much less impact (Klein, 1993). Sometimes the same type of recreation has different impacts in different situations. For example, Titus and VanDruff (1981) found that common loons *(Gavia immer)* deserted nests in response to motor boats, but not to canoes. Rodgers and Smith (1995) observed that double-crested cormorants *(Phalacrocorax auritus)* flushed at a greater distance from canoes than from motor boats.

The impact of any type of recreation is also strongly influenced by the recreationist. Recreationists can typically reduce their disturbance impact by making their behavior appear less threatening. Maintaining a buffer distance and moving slowly, quietly, and tangentially are measures that tend to reduce the threat that wildlife perceive in humans.

Predictability can help wildlife adjust to non-threatening sources of disturbance. It can also cause habitat abandonment when disturbance sources are threatening. North American elk *(Cervus elaphus)*, for example have habituated to the regular presence of humans in western Montana (Thompson and Hendersen, 1998). However, Florida manatees *(Trichechus manatus latirostris)* in Crystal River, Florida reduced use of historical habitat and increased use of sanctuary areas in response to rising boat traffic (Buckingham, Lefebvre, Schaefer, and Kochman, 1999).

Frequency and magnitude of disturbance may have thresholds beyond which significant impacts can occur. Strawberry Point, for example, was a historic harbor seal haul-out area located along the suburban coast of Marin county in the San Francisco Bay. During the mid 1970s this site supported a wintering population exceeding 100 Pacific harbor seals *(Phoca Vitulina Richardsi)* (Paulbitsky, 1975). Since then, the site has been entirely abandoned by seals, due to increasing encroachment by development and trail use by pedestrians and dogs.

Timing can play a key role in the relative severity of human disturbance of wildlife. Two critical periods have been identified that apply to many species of birds and mammals. Birds are most vulnerable during the breeding period when they require significant energy resources to incubate their eggs. Disturbance during this period can negatively impact the survival of offspring (Gabrielsen and Smith, 1995). Mammals are most vulnerable during the immediate post natal period when offspring are fragile and incapable of flight. Newborn deer, for example will freeze in place to avoid detection when threatened. If they are touched by encroaching humans, parents will sometimes respond by abandoning them (Knight and Cole, 1995).

Finally, the location from which a disturbance arises can impact its level of severity. Hauled out seals in San Francisco Bay estuaries responded more strongly to people on land than to boats (personal observation). Bighorn sheep *(Ovis Canadensis)* were more disturbed by hikers approaching from above than from those approaching from lower levels on the hillside (Hicks and Elder, 1979).

One of the greatest challenges for wildlife managers is the degree to which wildlife responses to recreationists vary (Knight and Temple, 1995). Response is driven not only by the severity of the disturbance but also by the context within which the disturbance occurs. Different species vary in their responses and the response of individual animals is also variable.

Human Disturbance of Marine Mammals

In spite of their ability to dive deep and swim for long periods underwater, marine mammals are unable to escape human disturbance. In addition to the injury and death often suffered at sea by commercial fishing, whales, dolphins, sea lions, and seals in coastal areas commonly experience disturbance from commercial and recreational boating activities. Van Parijs and Corkeron (2001) observed an increase in communication and group cohesion by Pacific humpback dolphins *(Sousa chinensis)* in the presence of passing ships off the coast of Australia, while Constantine, Brunton, and Dennis (2004) demonstrated that bottlenose dolphins *(Tursiops truncates)* rested less as the number of whale-watching boats increased in New Zealand. Killer whale *(Orcinus orca)* pod movement appears to be affected by whale-watching operators that intentionally track them (Jelinski, Krueger, and Duffus, 2002). Humpback whale *(Megaptera novaeangliae)* mother and calf pairs have avoided near-shore areas where human recreational activity is high (Salden, 1988). Numerous West Indian manatees *(Trichechus manatus)* have been seriously injured or killed by motorboats along the east coast of Florida and Georgia (Deutsch, Reid, Bonde, Easton, Kochman, and O'Shea, 2003). These animals tend to increase their use of sanctuary waters when the number of swimmers and boaters increase in unprotected waters (King and Heinen, 2004).

Harbor seals experience disturbance at haul-out sites in many locations, which can affect their haul out behavioral patterns. Allen, Ainley, Page, and Ribic (1984) and Suryan and Harvey (1999) observed that harbor seals that are disturbed enough to flush into the water frequently remain in the water or swim off to different haul-out sites rather than re-hauling in the original location. Such activity requires increased energy expenditure and can be risky for individuals when haul-out space is limited. Sources of human disturbance at haul-outs include motorized and non-motorized boats, jet-skis, pedestrians, dogs and low flying aircraft (Renouf, Gaborko, Galway, and Finlayson, 1981; Allen et al., 1984; Terhune, 1985; Calambokidis, Steiger, Evenson, and Jeffries , 1991).

Harbor seals at the haul-out site routinely exhibit vigilance behavior, or active visual scanning of their environment. Galloway (2000) observed hauled out seals in San Francisco Bay and noted that rest and scanning constituted up to 97% of all behavioral activity. Scanning functions to detect potential predators (da Silva and Terhune, 1988) and might increase in response to increased disturbance levels. Terhune (1985) and Terhune and da Silva (1988) report that higher numbers of seals at a haul-out site increase the ability for the group to detect disturbance while allowing for decreased scanning activity for individual animals. Vigilance also decreases with time since haul out (Terhune and Brillant, 1996) supporting the idea that each disturbance event causing flight into the water interferes with immediate rest as well as post-recovery rest. Mothers with pups may be more sensitive to disturbance (Stein, 1989), although Suryan and Harvey (1999) report no difference in recovery after disturbance between pups, sub-adults and adults.

Pacific harbor seals inhabiting the San Francisco Bay have experienced relatively high levels of disturbance as a result of significant development over the past 50 years and the ease with which watercraft and trail users can access estuarine haul-out sites. Census data for the past 25 years indicates that while the population of seals at sites along the coast has steadily increased, the population within the San Francisco Bay has remained stable (Kopec, 1999). Grigg, Allen, Green, and Markowitz (2004) cite disturbance as a contributing factor. Primary sources of disturbance in the Bay include commercial and recreational boats, kayaks, personal watercraft, aircraft, foot traffic, and dogs (Allen and Markowitz, 2006). In addition, the seismic retrofit of the Richmond-San Rafael Bridge that took place from 2001-2005 imposed a significant disturbance on an important haul-out site at Castro Rocks in the Central part of the Bay, which is located next to the southeastern section of the bridge. Researchers at San Francisco State University coordinated efforts with the California Department of Transportation for the duration of the project in order to identify and minimize its impact on the seals (Allen and Markowitz, 2006).

Seal reactions to disturbance vary depending upon the frequency, magnitude and proximity of the disturbance as well as the tide level at the time of disturbance (Suryan and Harvey, 1999). Seals cope with disturbance by increasing their level of vigilance, moving closer to the water in preparation for escape, flushing into the water to escape and either returning to the haul-out site as the disturbance passes or leaving the original site in search of another place to come ashore. On occasion, long-term, high levels of disturbance have led to permanent abandonment of haul-out sites such as the aforementioned Strawberry Spit in the North San Francisco Bay. In other situations, where disturbance may be frequent, but less threatening, seals have become habituated to humans and tolerate their presence at least to some degree. Hauled out seals at the Elkhorn Slough, near Moss Landing CA, swim close to kayakers and remain in place as pontoon tour boats pass their haul-outs (Stienstra, 2005; personal observation).

Wildlife Habituation to Human Disturbance

Habituation is defined as the waning of a response to a repeated stimulus that is not associated with either a positive or negative reward (Eibl-Eibesfeldt, 1970). Many animals possess an ability to adapt to non-threatening humans in their environment, particularly species that are small, mobile and readily able to escape encounters if they become threatening. Songbirds, squirrels, rabbits, raccoons, opossum, deer, and even coyotes provide examples of wild animals that have adapted reasonably well to urban or suburban environments in the United States. Repetitive disturbance actually affects the ability of wildlife to habituate. Many behavioral and physiological disturbance responses will decrease in intensity and gradually disappear in the face of repeated human activities. Birds nesting close to humans, for example, tolerate more disturbance than those nesting in remote areas (Gabrielsen and Smith, 1985). Ungulates including adult reindeer *(Rangifer tarandus)*, mule deer *(Odocoileus hemionus)*, and moose *(Alces alces)* have demonstrated shorter flight distances in response to mechanical sounds than animals never exposed to such sounds (Freddy, Bronaugh, and Fowler, 1986; Tyler, 1991). In some situations, wildlife can become so habituated to humans that the physical risks for both become high. Mattson and Reid (1991) describe dangers associated with habituated grizzly bears *(Ursus arctos horribilis)* that became accustomed to human food hand outs in Yellowstone National Park. Thompson and Henderson (1998) and Kloppers, St. Clair, and Hurd (2005) describe the risks to both habitat and people by habituated elk *(Cervus elaphus)* in urban fringe areas of western Montana and in Banff National Park, Canada, respectively.

Like other wildlife species, marine mammals have exhibited at least some ability to habituate to humans in their environment. Connor and Smolker (1985) documented bottlenose dolphins (Tursiops *sp.*) in Western Australia voluntarily swimming into shallow waters, accepting fish handouts and varying amounts of physical contact. Short finned pilot whales *(Globicephala macrorhynchus)* tolerated small numbers of humans swimming in their proximity, when the swimmers moved slowly and maintained some distance between themselves and the animals (Scheer, Hofman, and Behr, 2004). Curious humpback whales *(Megaptera novaeangliae)* off Baja, CA have intentionally approached small tour boats in a calm manner and allowed themselves to be rubbed (Solmonson, 2005) and the common phenomenon of dolphin pods riding the bow waves of boats demonstrates a level of habituation to watercraft.

Engelhard et al. (2002) describe elephant seals *(Mirounga leonine)* which appeared indifferent to high or low human researcher presence at Macquarie Island Canada, although alertness rose as the number of people increased. Bonner (1982) and Johnson et al. (1989) note that seals in some cases habituate to disturbances near the haul-out site. Northern elephant seals *(Mirounga angustirostris)* at Ano Nuevo State Park Pescadero, CA allow tourists with naturalist guides to pass within close range as they haul-out during the breeding and pupping seasons and harbor seals hauled out on rocks near shore in Monterey Bay demonstrated tolerance of boaters and kayakers passing within a few meters (personal observation 2006).

While the habituation observed to specific activities may be beneficial to individual animals in the short run, the long-term effects of such habituation are unclear. Knight and Cole (1995) emphasize the need for better understanding of the role recreationists play in affecting wildlife because it may be more feasible for resource managers to change recreationist's behavior than the characteristics of wildlife that make them vulnerable to disturbance.

The study of wildlife disturbance and habituation presents challenges for researchers. Knight and Cole (1995) report critiques by other researchers, which claim many studies are too short in duration (Wiens 1984), lack adequate controls or replications (Hurlbert, 1984), have too many confounding variables, (Cooke, 1980) offer observations that are anecdotal.

Important questions such as how, specifically, non-threatening humans disturb wildlife, how and why some species habituate to humans in certain cases, and to what extent local populations may habituate to humans and still maintain their health and reproductive vigor. Studies that effectively address such questions will assist wildlife managers in allocating scarce resources to best protect wildlife while supporting human recreational needs.

Bair Island Refuge in Redwood City, San Mateo County, CA provides a valuable location to observe the interaction between recreationists and wildlife in a natural setting. The goal of Refuge managers is to protect a historic haul-out site for Pacific harbor seals while also providing opportunities for recreational boating. Efforts are also underway to restore historic tidal marsh habitat at the Refuge, which requires re-routing some of the water that flows through Corkscrew Slough for a period of time (Trulio et al., 2003). In a study examining the potential impact that flow restrictions might have on harbor seals, Trulio et al. (2003) confirmed the regular use of Corkscrew Slough by seals as well as frequent use of Redwood Creek and Corkscrew Slough by recreational boaters. Insights gained from the current study are intended to provide management information and to assist in the development of optimal boating policy at the Refuge.

Pacific Harbor Seal Ecology and Distribution

Pacific harbor seals *(Phoca vitulina richardsi),* belong to the family of *Phocid* or earless seals. They are quite distinguishable from their cousins the California sea lions (*Otara Zalophus californiaus*), which often share their coastal habitat. Harbor seals have rounded heads, short fore-flippers and a lack of external earflaps or any distinguishable neck. Sea lions have longer snouts, external earflaps and long fore-flippers which they use for walking on land. In addition, unlike sea lions, harbor seals cannot rotate their hind flippers underneath their bodies to walk and are therefore, awkward on land as they must move by lurching along on their bellies. Pacific harbor seals inhabit coastal waters along the west coast of North America from the Bering Strait to Baja California, often preferring estuaries (Orr and Helm, 1989) where shallow protected waters are available for foraging and rest (Torok, 1994). They are common in their range with total population estimates approximating 400,000 – 500,000 (Riedman, 1990) and California coastal estimates around 32,000 (NMFS, 1997). Harbor seals are been protected by the Marine Mammal Act of 1972 and the U.S. coastal population has been increasing at a rate of 5-7% per year since the mid 1970s (NMFS, 1997).

Harbor seals are highly adapted to life in the sea, possessing a thick layer of blubber that provides warmth and energy reserves during pupping season when the animals fast for extended periods of time (Riedman, 1990). Their streamlined body forms make them superbly graceful underwater as they swim using lateral, sculling movements by their powerful hind flippers and lower bodies (Riedman, 1990).

Like other *Pinnipeds*, harbor seals can remain underwater for extended periods of time and are capable of diving to great depths when foraging without suffering organ damage or nitrogen narcosis (Ridgeway, 1972). When diving, they conserve oxygen by constricting their peripheral blood vessels and slowing their heart rate (Newby, 1978). Harbor seals have large eyes and excellent visual acuity both above and below water. On land their vision is said to rival that of a cat (King, 1983). They hear extremely well underwater and their profuse set of whiskers, or vibrissae, can detect the vibrations of their prey, most commonly fish and invertebrates (Riedman, 1990).

Individual harbor seals demonstrate a wide variation in coloring, ranging from dark brown or black to silver-grey with dark or white spots (Orr and Helm, 1989).

Newborn pups are typically a speckled grey. Many seals in the San Francisco Bay have a red pelage, due probably to the deposition of ferric oxides that are present in the water (Allen, Stephenson, et al., 1993).

Harbor seals are not sexually dimorphic. Adult females and males weigh between 70 – 100 kilograms, and measure about 1.5 meters in length. Average life span approaches thirty years (Newby, 1978). Harbor seals mate in the water. Males do not establish land territories with harems as do some other *Pinnipeds*, but appear to compete with one another by performing dominance displays underwater, with splashing, bubble blowing, flipper-slapping, and underwater vocalizations (Berger, 1996). Pupping season in the San Francisco Bay runs between mid March and the end of May, with the numbers of pups peaking in late April or May (Allen et al 2006). Mothers nurse their young for 4-6 weeks, during which time they do not feed regularly. If a mother is separated from her pup during this initial period, the pup is likely to die (Bartholomew 1949, Calambokidis et al. 1978, Allen et al 2006). Pups weigh 20-26 pounds at birth and will double their weight during the nursing period (Newby, 1978). Females are devoted parents, playing with the pups, carrying them on their backs, and developing their swimming abilities (Newby, 1978).

Harbor seals are top predators in the marine food chain. San Francisco Bay seals are non-migratory, moving only about 100-300 kilometers seasonally as they forage (Torok, 1994) and on a short-term basis as little as 3 – 7 km from their haul-out sites (Harvey and Torok, 1994).

Harbor Seals are opportunistic feeders that prey on a wide variety of fish, cephalopods and vertebrates depending upon seasonal and regional availability of prey (NMFS, 1997; Harvey and Torok, 1994). Goby, sculpin, and croaker dominate their diet in the South Bay while mid-shipman are more common in the Central Bay. Seals forage more frequently at night (Torok, 1994) which allows them to haul out and rest during the day (Newby, 1978).

Importance of Hauling Out

Adapted to the sea as they are, *Pinnipeds* still spend considerable amounts of time on land, to rest, thermo-regulate and bear and nurse their offspring (Riedman, 1990). Kopec (1999) describes how the very survival of harbor seals depends upon their ability to haul-out on land on a regular basis. When swimming in cold water, a seal's core body temperature is maintained by metabolic heat production and its insulating layer of blubber. But, the longer the seal remains in the water, the higher its metabolic activity must rise in order to compensate for heat loss and to prevent depletion of its blubber layer. This increased heat production must be fueled by eating more fish, which requires expending more energy and remaining in the water longer. Hauling out reduces the thermal stress on seals by reducing the need for metabolic heat production and also provides them with physical respite and a chance for surface wounds to heal (Kopec, 1999).

Haul-out sites must have gently sloping terrain with immediately adjacent deep water (Allen, 1991). If a disturbance occurs they can immediately flee to the water and will sometimes rest on the bottom assuming a vertical position called "bottling" (Newby, 1978). Seals persist at the same haul-out sites over time and are resistant to discovering and using new pupping sites (Allen, 1991). For this reason, the protection of existing haul-out sites in the San Francisco Bay is crucial to the well-being of this species. Excessive disturbance at haul-out sites can disrupt haul-out activity and thereby lead to increased physiological stress, altered haul-out behavior, and potentially abandonment of a haul-out site. Because seals are reluctant to discover new sites, protection of every existing haul out site is important to protection of the population in San Francisco Bay. Figure 1 shows the active and historical harbor seal haul-outs in the San Francisco Bay.

Haul out sites in the San Francisco Bay can be grouped around two general feeding areas described by Kopec and Harvey (1995). The Central Bay area includes waters between the Golden Gate Bridge and Treasure Island, extending northwest to the Tiburon Peninsula and somewhat south of Yerba Buena Island (Goals, 2000). Nine haul-out sites are associated with this feeding area, Yerba Buena Island and Castro Rocks being the largest (Figure 1). The South Bay feeding area includes open Bay waters from the San Mateo Bridge Southward (Goals, 2000). This feeding area supports thirteen haul-out sites, seven which are located on the southeastern and southernmost tip of the Bay and six which are located on the west side of the South Bay (Figure 1). Mowry Slough represents the largest pupping site in the South Bay, with 78 and 90 pups counted during the 1999 and 2000 pupping seasons, respectively.

Bair Island Refuge includes Outer Bair Island and Corkscrew Slough, two of the six recognized haul-out sites on the west side of the South Bay. Three others, Greco Island, Belmont Slough and Ravenswood Point, lie within 10 kilometers of Bair Island (Figure 1). Historical census data for these haul-out sites are minimal and sporadic. Some data were obtained through ground based observations and others by aerial survey. Kopec and Harvey (1995) summarized seal counts in the South Bay performed by various researchers since the 1930s. Single counts of 40 and 33 seals were obtained by Bartholomew (1949) at Belmont Slough and Ravenswood Point, respectively between 1930 and 1945. Nine counts at Greco Island between 1960 and 1992 ranged from 5-66 seals. The earliest record of seals at Corkscrew Slough was a count of 25 adults and pups during spring in the late 1950s, reported by Paulbitsky (1976). Alcorn and Fancher (1980) counted 0-12 seals during three surveys in the winter/spring of 1975-1976, but a single survey in 1979 found no seals. Fancher (1987) reported one pup, but no adults in 1980. Harvey and Kopec (1995) reported maximum adults of 18 and 1 respectively, during the 1981 and 1982 pupping seasons, and maximum adults of 6 and 20 during the non-pupping seasons in 1981 and 1982. Few data are available for the remote haul out site at Outer Bair Island. The only recorded counts are by Harvey and Kopec (1995) who conducted ground based surveys and reported adult counts of 30 and 5, respectively for the 1991 and 1992 pupping seasons and 21 and 19, respectively for the non-pupping season during those same years. The census data obtained during the current study will provide valuable baseline information for future population trend analysis if data collection is continued over time.

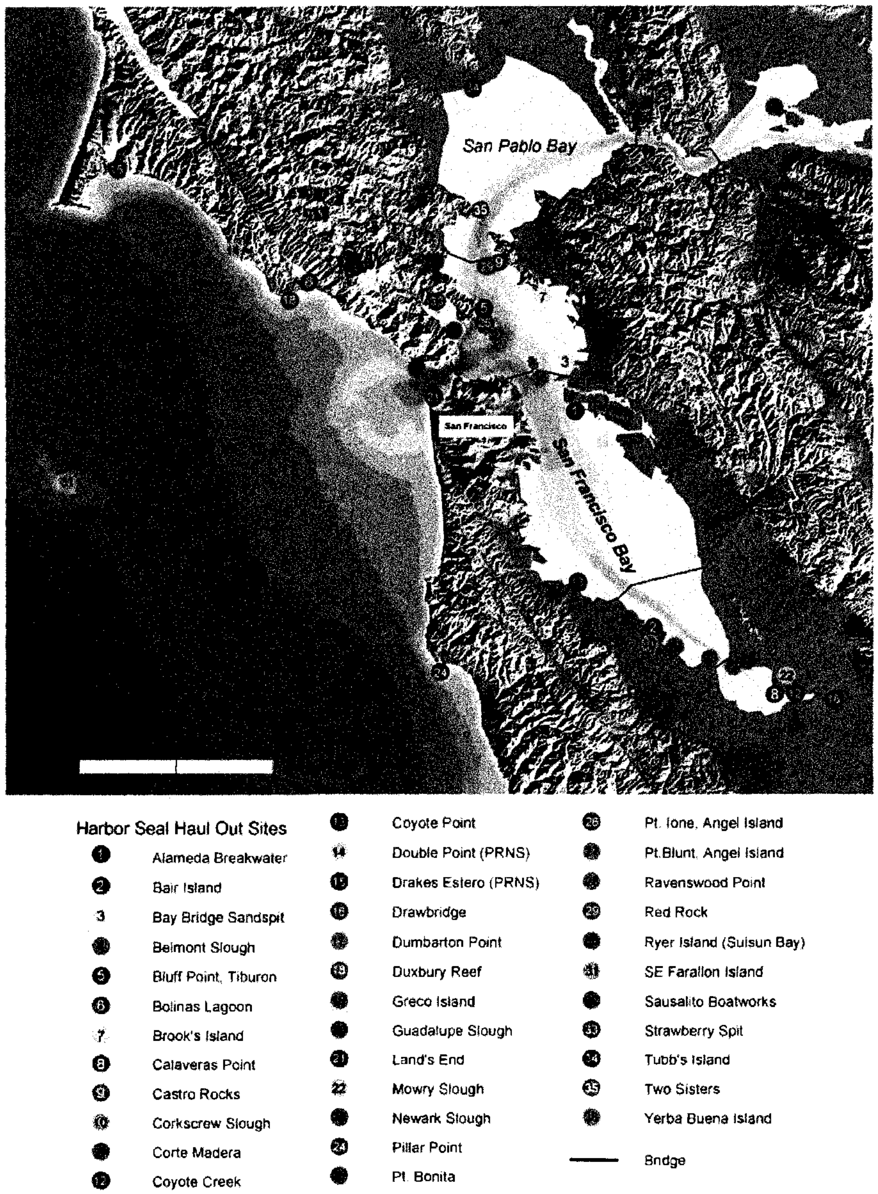


Figure 1. Map of active and historical harbor seal haul-out sites in San Francisco Bay.

Bathymetry data: California Dept. of Fish and Game, Teale Data Center, California digital elevation model. Land relief data: USGS, SF Bay Region shaded relief map. (Reprinted with permission. Emma Grigg, *Richmond Bridge Harbor Seal Survey Final Caltrans Report – January, 2006*).

Hypotheses and Research Questions

This study was designed to obtain baseline population data and to analyze the effect of recreational boating on the behavior of harbor seals that haul out within the Bair Island Refuge in San Francisco Bay. Information gained through this study will assist refuge personnel in managing the seal population developing boating policy that is mutually beneficial to seals and recreational boaters. I addressed four research questions and two hypotheses.

Research Questions

1. What is the size and character of the harbor seal populations at Corkscrew Slough and Outer Bair Island and has the population changed over time?
2. What type of boating activity occurs within Corkscrew Slough and what is the daily/seasonal frequency of such boating?
3. How does the frequency of seal encounters with boats at Corkscrew Slough compare with the frequency of seal/ boat encounters at other haul out sites in the San Francisco Bay?
4. Do harbor seals demonstrate any apparent habituation to boaters in Corkscrew Slough?

Hypotheses

Ho1: There is no significant difference between the number of harbor seals that haul out at Corkscrew Slough when boats are present or absent or in the vigilance behavior of seals (as measured by alert versus relaxed responses) when boats are present or absent.

Ho2: There is no significant difference in harbor seal disturbance response (as measured by Relaxed, Alert, Disturbed, and Flush responses) to different types of boat (paddle, motor, row) or to boat characteristics including number of boats, number of boaters, boat orientation, boat speed, boat noise, boater behavior and distance of boat from haul out site.

Methods

Study Site

The study was conducted at Bair Island Refuge, a 2600 acre tract of tidal marsh, sloughs, and mudflats located in Redwood City, California, approximately 25 miles south of San Francisco. Part of Don Edwards National Wildlife Refuge, Bair Island provides important haul-out habitat for harbor seals as well as wetland habitat for more than 125 species of birds, 13 mammals, 63 species of fish, and large numbers of birds traversing the Pacific Flyway. Two endangered species, the California clapper rail and the salt marsh harvest mouse, are residents (USFWS, 2006). Bair Island is an important urban refuge because the surrounding region has been extensively developed. Adjacent land uses include several boat harbors, an airport, a sewage treatment plant, salt ponds, Interstate Highway 101, and residential and commercial developments. In addition to providing wildlife habitat and flood protection, Bair Island is used extensively for a variety of recreational and educational purposes (Trulio et al. 2003). Significant habitat restoration efforts are in progress at Bair Island as the U.S. Fish and Wildlife Service and the California Department of Fish and Game work to restore tidal action to 1,400 acres of former salt ponds on the site. Serious attention is being paid to avoid disturbing the historical seal haul-out sites within the reserve.

Observation Sites

Seal observations were made along Corkscrew Slough and at Outer Bair Island, two historical haul-out sites within Bair Island Reserve. Corkscrew Slough separates Middle Bair and Outer Bair Islands as it winds a circuitous path for approximately three nautical miles between Redwood Creek and Steinberger Slough (Figure 2). Seals enter Corkscrew Slough from Redwood Creek and typically haul out along a 725 meter stretch of the Slough. Corkscrew is deep enough for seals to access the haul out area from Redwood Creek at low tides and it likewise remains navigable for small boats at all but the lowest of tides. Seals haul out often along the northerly shore of the slough where sharply sloping mud banks provide ready escape to the water and the flat pickleweed plain provides ample haul out space and an expansive view of the surrounding area. Recreational boaters can enter Corkscrew Slough either from Redwood Creek or Steinberger Slough, but the majority enter from Redwood Creek which is much deeper, wider and closer in proximity to local boat launch sites. Seal use of Steinberger Slough is negligible, due to its shallow depth at lower tides, when exposed mudflats prevent their passage (Trulio et al. 2003).

The first observation location Corkscrew Slough 1, (CS1), allowed viewing of seals hauled out along a 325 meter stretch of the slough beginning where Corkscrew Slough makes a sharp northwesterly bend and ending at a second sharp northerly bend (Figure 2). Seals haul out along the northern banks of this site, most commonly in groups just beyond the first bend. The second observation location Corkscrew Slough 2, (CS2), allowed viewing of seals hauled out along the 400 meter curving stretch, just past the second bend and extending along a wide open body of water to a third bend where the slough narrows once again (Figure 2). Seals haul out along the length of the northern banks of this site also, most commonly grouping in one of three spots where the seals all remain visible to one another. While the two haul out sites defined for this study (CS1 and CS2) are not independent of each other and represent one contiguous haul-out area, the seals at CS1 cannot see the seals at CS2. Nor could I observe all of the seals at CS1 and CS2 at the same time when seated at the CS1 observation point, due to the bend in the slough and the distance between the haul-outs (approximately 700 meters). The area was intentionally divided into two sites for the study so that the researchers could observe seal response to boaters as they passed by.

The haul-out site at Outer Bair Island is quite remote for recreational boaters because of its distance from the boat launch (approximately 4500 meters) and the fact that boaters must either go out into the open Bay or follow a circuitous, unmarked route through sloughs and borrow ditches in order to get there. Seals however, can access the haul-out from the Bay. This site is defined by a trio of narrow, shallow sloughs that are protected from the open bay by a small peninsula that sits some 30 meters offshore of Outer Bair (Figure 2). Seals haul out on flat, narrow mudflats along these sloughs, which are quite sequestered but offer no view of potentially approaching boats. Due to the shallow bathymetry of the surrounding waters, this site was not accessible to the research raft at lower tide levels. Observations at Outer Bair were limited to seal counts at higher tides and observations of their behavioral responses to the research raft, since no other boats were ever seen approaching this location.

Observation Protocols

Data was collected between March 11, 2006 and June 23, 2007 during fifty-eight field sessions which totaled 185 hours of observation. Field sessions took place between the hours of 0800 and 1900, at various tide levels, on both weekdays and weekends.

Sessions lengths varied between two and six hours, most commonly lasting four hours. Session lengths varied between 2 and 6 hours (most lasting 4 hours) due to weather conditions, tide levels impacting access to the slough and availability of research assistance. Due to the relative remoteness of the haul-out sites, two researchers were typically present during observation sessions.

Harbor seals at Corkscrew Slough were observed from ground-based observation points (CS1 and CS2) located on the opposite side of the Corkscrew Slough waterway from the haul out sites. Observations were made using Nikon 8 X 20 field binoculars. Distances were estimated using a Bushnell Yardage Pro 400 Optical Range Finder.

Researchers approached the observation points on foot moving slowly and steadily in order to refrain from drawing the attention of the seals. Once researchers were sitting in place motions were kept to a minimum. Due to the extremely flat terrain of the marsh plain it was impossible for researchers to observe the seals without being viewed to some degree in return by the seals. While the use of blinds was considered, this idea was rejected as infeasible because the seals best view of the researchers occurred as the researchers approached their observation points on foot; once seated, the researchers could lie down or crouch low enough to avoid being seen. In addition, while the most heavily used spot at the CS1 haul-out site was reasonably close to the CS1 observation point (about 100 meters directly across the slough), the haul-out spots along the extended stretch of CS2 were much further away from the CS2 observation point (200-300 meters across the slough) and seals at CS2 paid virtually no attention to the researchers.

Access to the observation points required boating and walking. Two researchers would launch a 12 foot inflatable raft with a 9.9 hp engine at the Redwood City public launch ramp and motor approximately 1.2 nautical miles along Redwood Creek before turning into Corkscrew Slough and proceeding another 450 meters to a PG&E pier located on Middle Bair Island. After docking the researchers would walk 485 meters to reach the CS1 observation point and an additional 265 meters to reach the CS2 observation point.

A permit for access to the marsh was obtained by the U.S. Fish & Wildlife Service. While the public is allowed to access the slough by watercraft, walking on the land is illegal. IACUC approval from San Jose State University was also obtained prior to implementation of the study.

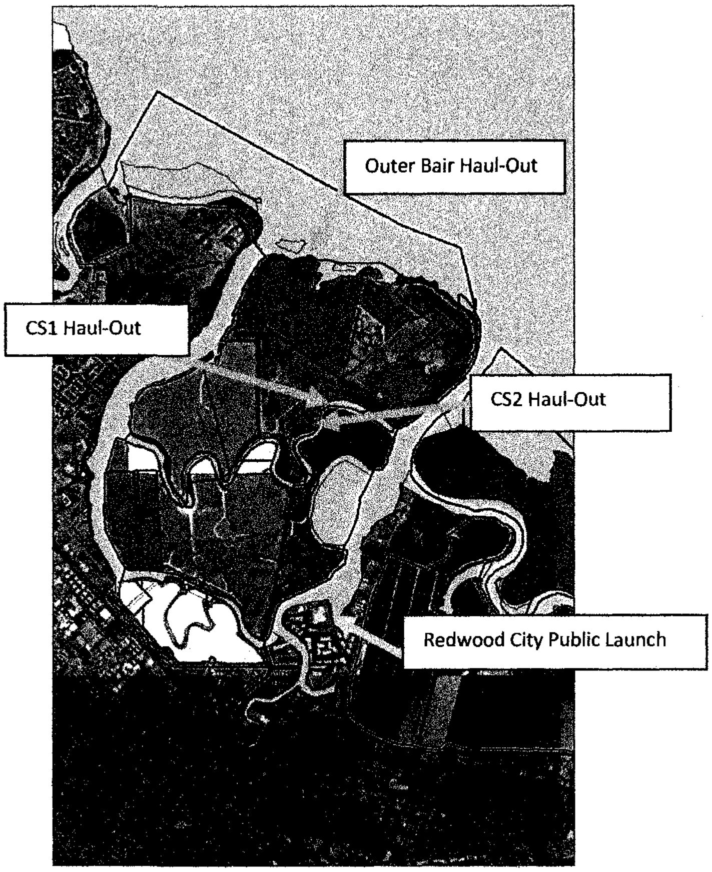


Figure 2. Bair Island haul-out sites: Outer Bair, Corkscrew Slough CS1 and CS2.

Numbers of seals and baseline vigilance behavior were recorded every ten minutes for the duration of every observation session. Counts included total number of seals hauled out and estimated age of each seal. Due to the difficulty in distinguishing between juveniles and adults seals were counted as either adults or pups. Seal "vigilance level" was defined as "relaxed" or "alert" according to a seal's posture, head position and open versus closed eyes (Figure 3).

In addition, during one ten minute interval of every half -hour period, scanning activity by all hauled out seals was recorded. Scans were defined as any head, neck or body movement made by a seal that would serve to increase its field of view. This definition is consistent with that used by Terhune (1985) in his study of harbor seal scanning behavior in the Bay of Fundy. Such scans served as a measure of "baseline vigilance" or attention to the surrounding environment and they clearly separate alert seals from seals that are asleep or completely relaxed. The total number of scans made by all hauled out seals at the site during these 10 minute intervals, called "group scans", were divided by number of seals in the group to give a relative measure of seal vigilance once every half hour.

In addition to the baseline counts and vigilance data, all boating activity and seal "disturbance response" to boats was recorded. As boats passed by the haul- out site, the following characteristics were recorded: boat type, number of boats, number of boaters and boat orientation with respect to the haul -out site (CS1 or CS2). In addition, boat distance from the haul- out site, boat speed and noise, and boater movement and boater noise were recorded (Table 1).

Table 1. Boat and Boater Characteristics

	Level
Boat Type	Paddle, Motor, Row
Boat Orientation	1= parallel to HO, 2= toward HO, 3= away from HO
Boat Distance	1= < 50 meters, 2= > 50 < 100 meters 3 = > 100 meters
Boat Speed	1= no wake speed, 2 = wake speed, 3 = very fast
Boat Noise	1= Quiet, 2= some engine noise, 3= very loud
Boater Movement	1 = Still or paddling 2= Waving, leaning over side, active
Boater Noise	1= Quiet, 2= Loud

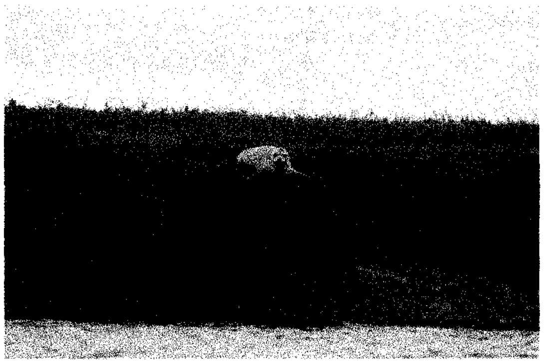
Boat type included three categories: paddle boats (including kayaks, canoes and outrigger canoes), motor boats (any size with any horsepower engine, including inflatable rafts, aluminum boats, water ski boats, motor-yachts, jet skis, waverunners, and airboats), and row boats, which were propelled by any type of oars. During some observation sessions, one of the researcher crew would motor past the haul-out in the research raft so that seal responses could be observed. Responses to the research raft were recorded in the same manner as for all other boats.

Seal disturbance responses were categorized as “relaxed”, “alert”, “disturbed” or “flushed” depending upon their physical actions as boats passed by (Figure 3). These categories are similar to those used in other studies observing seal response to disturbances (Suryan & Harvey 1999, Allen et al 2006). “Recovery” was defined as any seal returning to land after having flushed into the water in response to a disturbance. Seals were not tagged, so whether seals hauling out after a disturbance occurred were the same ones that had flushed could not be verified for certain. Recovery times were recorded whenever possible. Field notes were maintained to describe behaviors and occurrences of interest including seal responses to one another, mother- pup interactions and disturbances unrelated to boats.

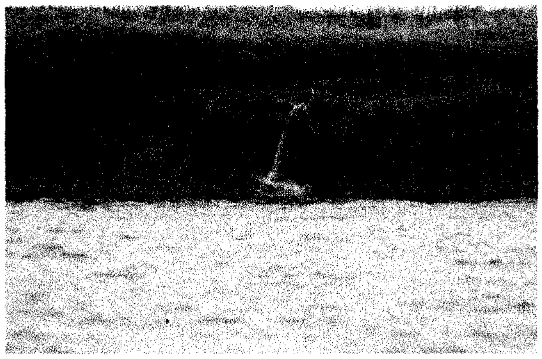
Paired counts of harbor seals at both Outer Bair Island and Corkscrew Slough were conducted on 19 separate occasions during the study. The paired counts were performed as close as possible in time in order to assure that there was little or no movement of seals between haul out sites that might result in double counting. Seals at Outer Bair Island were counted from a point on the peninsula sequestering the haul out site or by the researchers as they motored past the haul -out site in their raft. Seal responses to researchers motoring past the haul-out were recorded.

1) Relaxed

2) Alert



3) Disturbed



4) Flush

Figure 3. Seal Vigilance Behavior and Response to Boats.

1) Relaxed – seal is prone, eyes closed or semi-closed, body and limbs relaxed, not paying attention to surrounding environment.

2) Alert – seal raises head and/or turns neck in order to focus eyes on a specific object or area of the environment.

3) Disturbed – seal raises body and moves fore-flippers in position for moving toward the water, but does not enter water.

4) Flush – seal enters the water. Baseline vigilance behavior is either Relaxed or Alert. Response to Boats or other Disturbance is Relaxed, Alert, Disturbed or Flush.

Statistical Analysis

Descriptive statistics were used to compare seal counts at Corkscrew Slough and Outer Bair Island, frequency and types of boat traffic at Corkscrew Slough and frequency of boat disturbances at various haul outs around the San Francisco Bay.

General Linear Models were used to test whether seal vigilance levels or total number of seals present at the haul out were the same during sessions when no boats were present versus sessions when boats were present. The dependent variable, "Percent Relaxed", was arcsine transformed and the dependent variable "Total Seals" was log transformed. Data from both CS1 and CS2 haul- out sites were pooled. Boats were present during 31 observation sessions and no boats were present during 10 observation sessions.

General Linear Models were also used to compare seal vigilance and total numbers of seals during the 10 minute period preceding the" first boat event" of the session, immediately after the boat event, during the first 10 minute period after the boat event, the second 10 minute period after the boat event and during the third 10 minute period after the boat event. This same procedure was used to compare seal vigilance and total number of seals during sessions when "multiple boat events" occurred.

A post hoc analysis was performed for the first boating event and for multiple boating events during a session in order to determine whether pre-event and post event levels of relaxation were different.

Results

Harbor seals were observed year-round at both Corkscrew Slough and Outer Bair haul- out sites with peak numbers occurring during the annual pupping season between March and July. Maximum counts of 58 and 54 seals were obtained at the combined sites during the 2006 and 2007 pupping seasons, respectively (Figure 5). A maximum count of 31 seals was obtained during the 2006 non-pupping season August – February. Maximum pup counts were 6 and 11 respectively, during the 2006 and 2007 pupping seasons. Paired counts of seals at Corkscrew Slough and Outer Bair haul outs showed peak numbers at Outer Bair were higher by 15-19 seals than the peak of 20 recorded at Corkscrew on paired count days (Figure 6). Total seal counts were probably understated at both locations for three reasons: 1) sleeping seals lie very flat in the marsh plain and often remain unnoticed unless they lift their heads to scan, 2) seals often lie so close to one another that some seals are blocked from view by the bodies of others, 3) seals hauled out within small inlets that branch off of the main channel are not visible to the researchers.

Seal counts at Corkscrew Slough were similar on weekdays and weekend days (Figure 7) while numbers of boats were higher on weekends than weekdays (Figure 8). Boats were observed year round at Corkscrew Slough. Levels of boat traffic were higher during the non-pupping season (August – February) than during pupping season (March – July) (Figure 9).

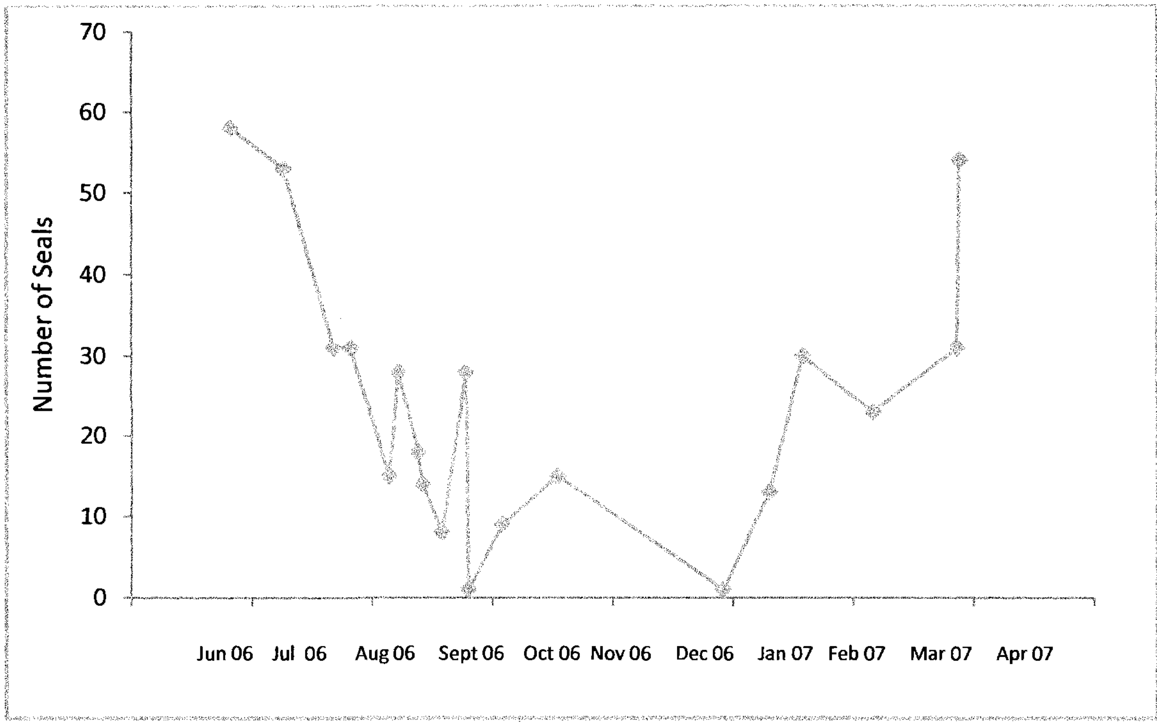


Figure 4. Seal counts: Corkscrew Slough and Outer Bair haul-outs June 2006 - April 2007.

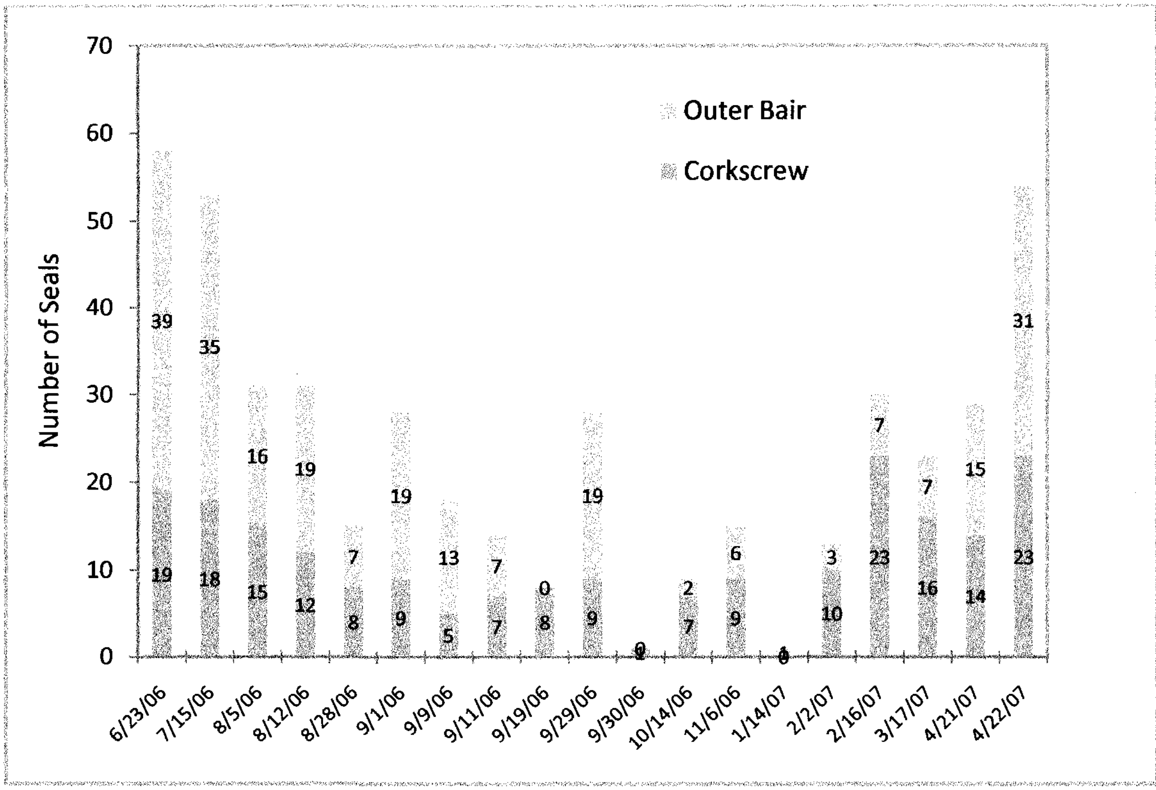


Figure 5. Paired seal counts at Corkscrew Slough and Outer Bair Island haul-out sites.

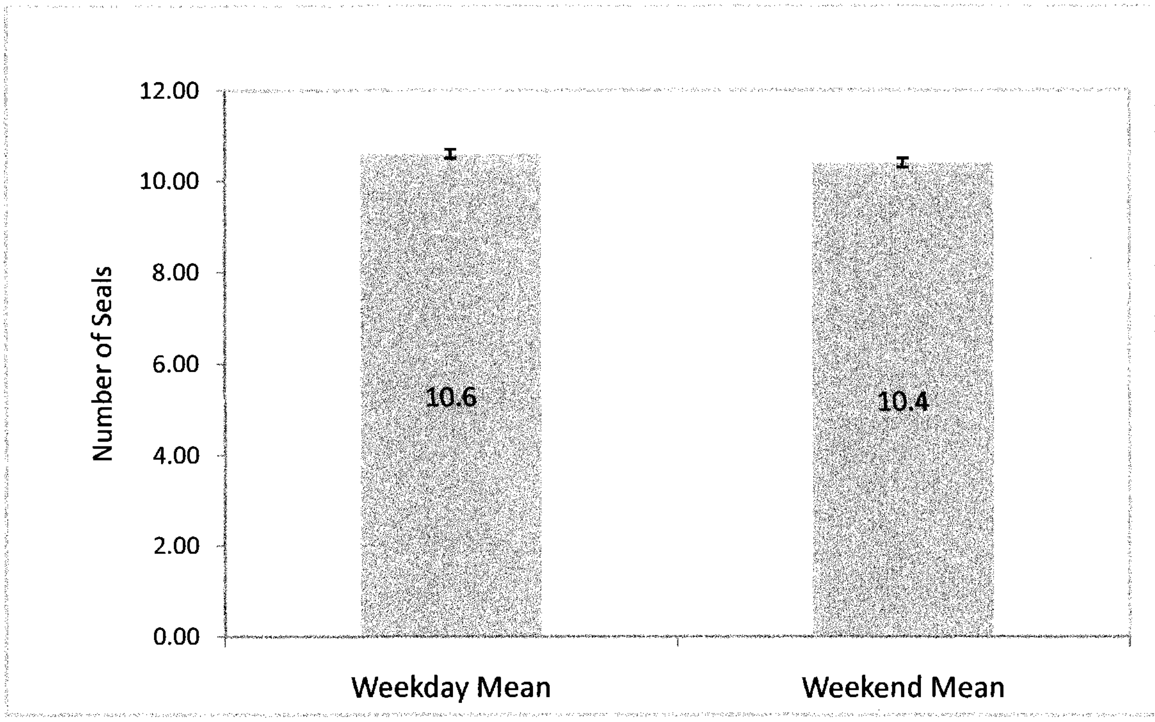


Figure 6. Mean seal counts at Corkscrew Slough haul-out weekdays versus weekends.

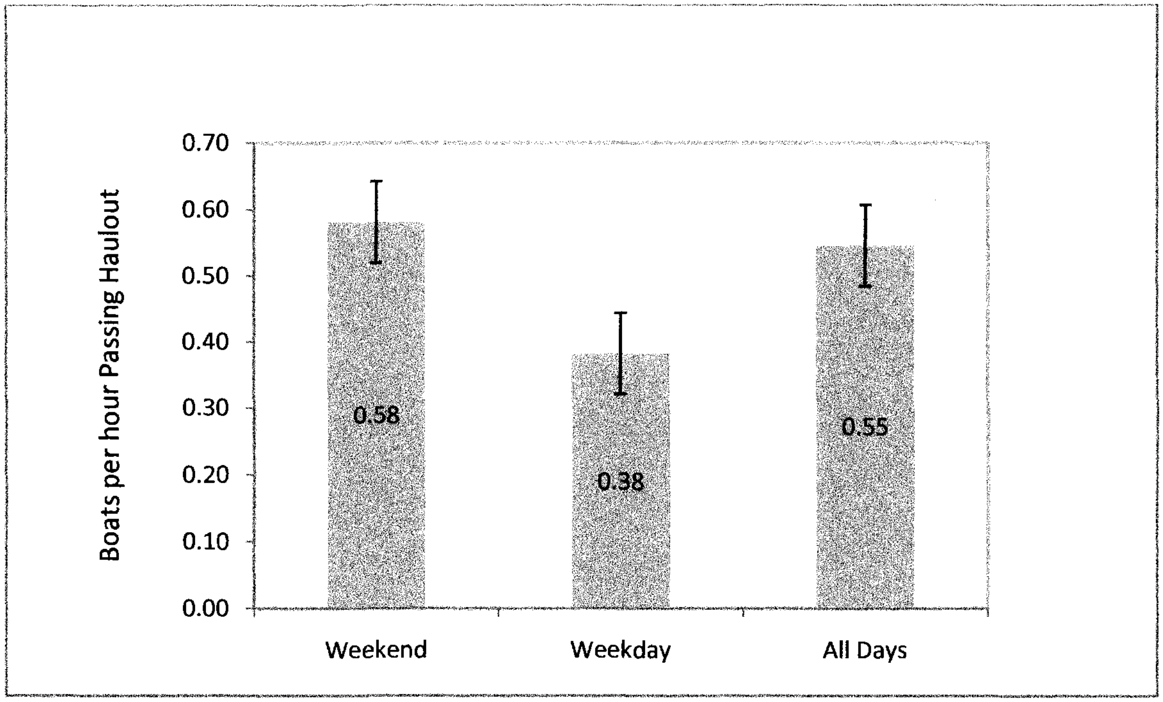


Figure 7. Boats/ hour passing Corkscrew Slough haul-out weekdays versus weekends.

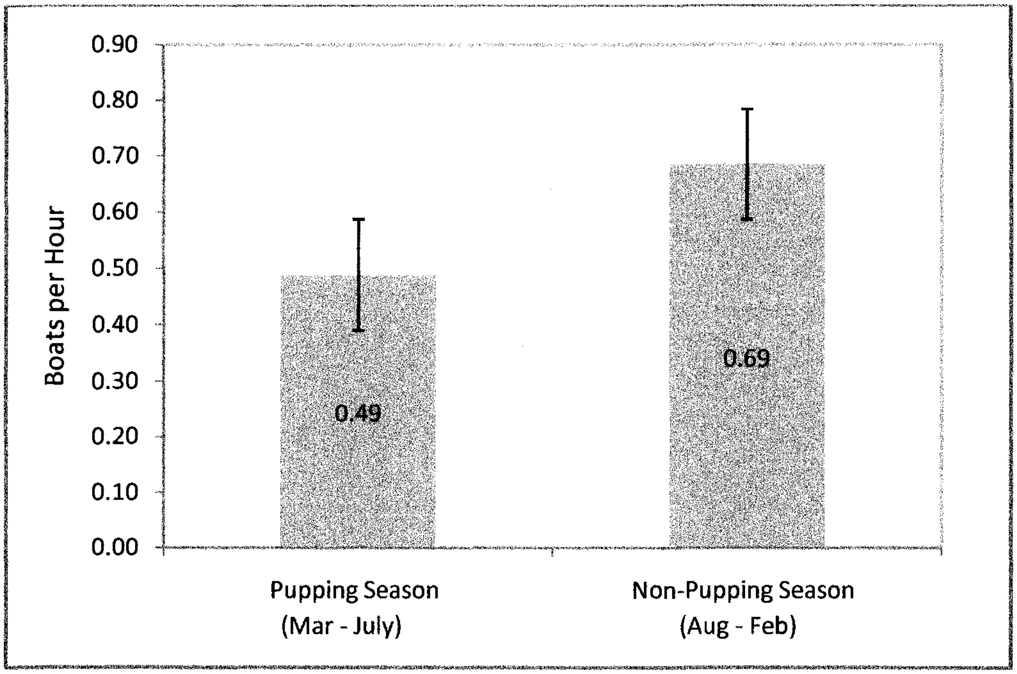


Figure 8. Boats per hour passing Corkscrew Slough haul-out Pupping - Non-pupping seasons.

A total of 101 recreational boats passed through Corkscrew Slough during the study. Researchers in the motorized raft passed the haul-out site on 11 occasions, bringing the total number of boat events to 112. Motor boats accounted for 55 of total boat events, paddle boats, 45, and row boats, 12. The majority of motor boats were inflatable rafts or small aluminum craft with 25 horsepower or smaller engines, but large ski boats and motorized yachts were observed on several occasions at higher tides. Personal watercraft (waverunners and jet skis) were observed on four occasions and an airboat passed the haul out on one occasion. The majority of paddle boats were single or double person kayaks, but outrigger canoes were observed on 2 occasions and standard canoes were observed on 2 occasions. Typically boats passed by the haul out site alone or in small groups of two to four. During February, 2007 however, an annual kayak race sponsored by a local paddling club brought a field of 37 single and double person kayaks and outrigger-canoes through Corkscrew Slough. Within a period of 20 minutes the racers passed both CS1 and CS2 haul outs, pivoted around a race buoy anchored some 40 yards beyond the CS2 haul out and returned past CS1 and CS2 again as they paddled back toward Redwood Creek. Oar (row) boats were observed on 12 separate occasions and all represented the long narrow scull type boat typically used for exercise or racing. Most of these boats had single rowers, but two boats with 5-6 rowers each were observed on one occasion.

During 185 hours of field observations at Corkscrew Slough 101 boating events were recorded (excluding the research raft), a rate of 0.55 boats/hour passing the haul out site. As boats took an average of about 1 minute to pass seals at the haul out sites, seals encountered boats of all types less than 1% of the time they were hauled out during daylight hours. No boats were observed during the 19 count sessions at Outer Bair Island.

There was no difference between the number of seals hauled out when boats were present or absent ($F_{(1, 39)} = 0.476$, $p = 0.494$) (Figure 9) nor was there a difference between the percent of seals relaxed during sessions when boats were present versus sessions when boats were absent ($F_{(1, 39)} = 0.126$, $p = 0.724$) (Figure 9).

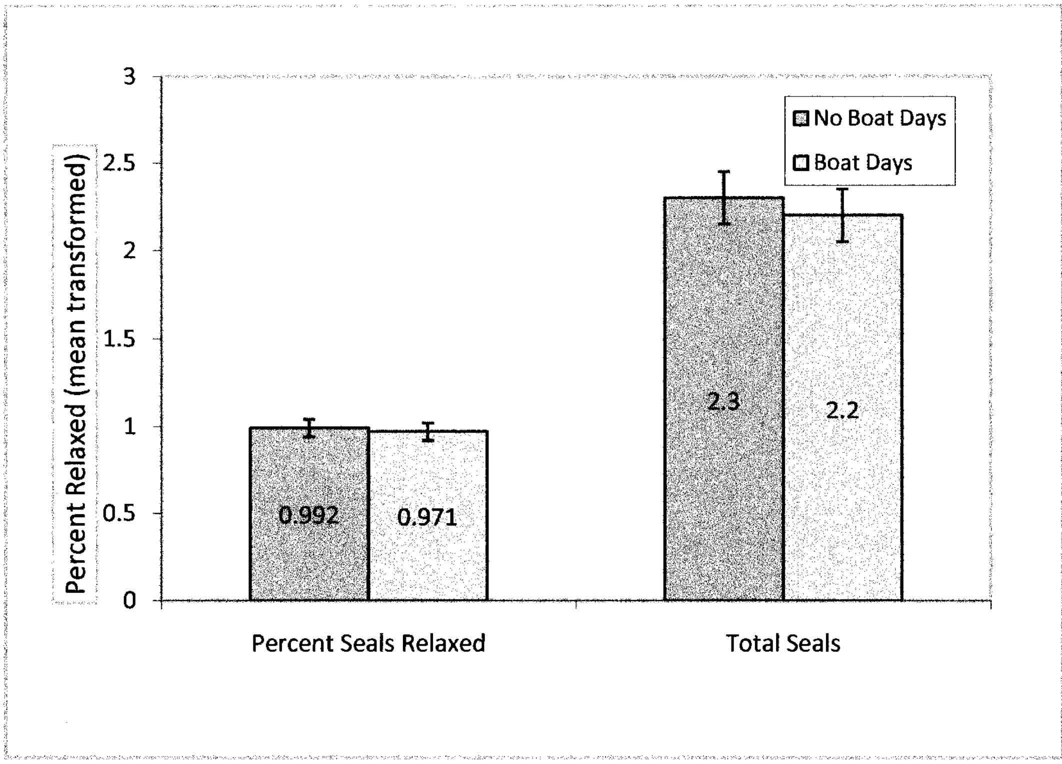


Figure 9. Percent seals relaxed and total seals when boats are present versus absent.

Comparing the percent of relaxed seals before, during, and after the first boat event of the session shows a significant drop in the percent relaxed as a boat passes by with recovery to pre-event levels within 10 minutes ($F_{(4,74)} = 5.723$, $p = 0.000$) (Figure 10). In addition, pre-event and 10 minute post –event means were comparable to the percent relaxed mean during sessions when no boats were present (Table 2).

Total seal numbers at the haul- out site also decreased at the time of the first boat event and then recovered over the following 30 minute period to levels comparable to that prior to the event ($F_{(4, 79)} = 0.797$, $p = 0.531$) (Figure 11).

A similar vigilance pattern is demonstrated during sessions with multiple boat events ($F_{(4,136)} = 14.300$, $p = 0.000$ (Figure 12). The percent of relaxed seals drops significantly as a boat passes, but recovers to pre-event levels within 10 minutes. Again, pre-event and 10 minute post –event means were comparable to the percent relaxed mean during sessions when no boats were present (Table 3).

During multiple event sessions, the number of seals declined at the time of boat events and recovered within a 30 minute period to levels similar to that prior to the event ($F_{(4, 140)} = 1.560$, $p = 0.188$ (Figure 13). However, the total number of seals during these sessions was well below the mean during sessions with no boats.

Seals responded to boats passing the haul out site by remaining relaxed or alert during 81 of the 112 boat events or 72% of the time, flushing into the water in response to 31 events, or 28% of the time. Flushes caused by boats occurred at a rate of 0.17 per hour. Compared to flush rates at four other haul-out sites in the San Francisco Bay the rate at Corkscrew Slough was relatively low (Figure 14). Paddle boats were the cause of 17 flush events, motor boats caused 11 flush events, and row boats caused 3 flush events. While motor boats represented 49% of total events they resulted in only 35% of flush events. Paddle boats represented 40% of total events but resulted in 55% of flush events. Row boats represented 11% of total events and 10% of flush events (Figure 15).

Boat characteristics including boat speed, boat noise and boat orientation toward the haul out site did not impact seals' likelihood of flushing nor did boater characteristics including number of boaters, boater noise or boater movement. Seal vigilance however, increased as boats passed closer to shore ($F_{(2,108)} = 5.221$, $p = 0.007$ (Figure 16).

Researchers walking to the observation bases at Corkscrew Slough both increased seal vigilance and caused seals to flush on a number of occasions. Once researchers were seated in place and refrained from moving around, seals ignored them.

Seals scanned less frequently as total number of seals increased on days when boats were present ($N = 31$, $R^2 = .432$) (Figure 17).

Seal vigilance and total numbers of seals for first events and multiple events were compared to average vigilance and average numbers of seals present at the haul-out during sessions when there were no boat events.

A linear regression analysis was performed to determine whether seals scanning activity was affected by the number of seals at the haul-out site.

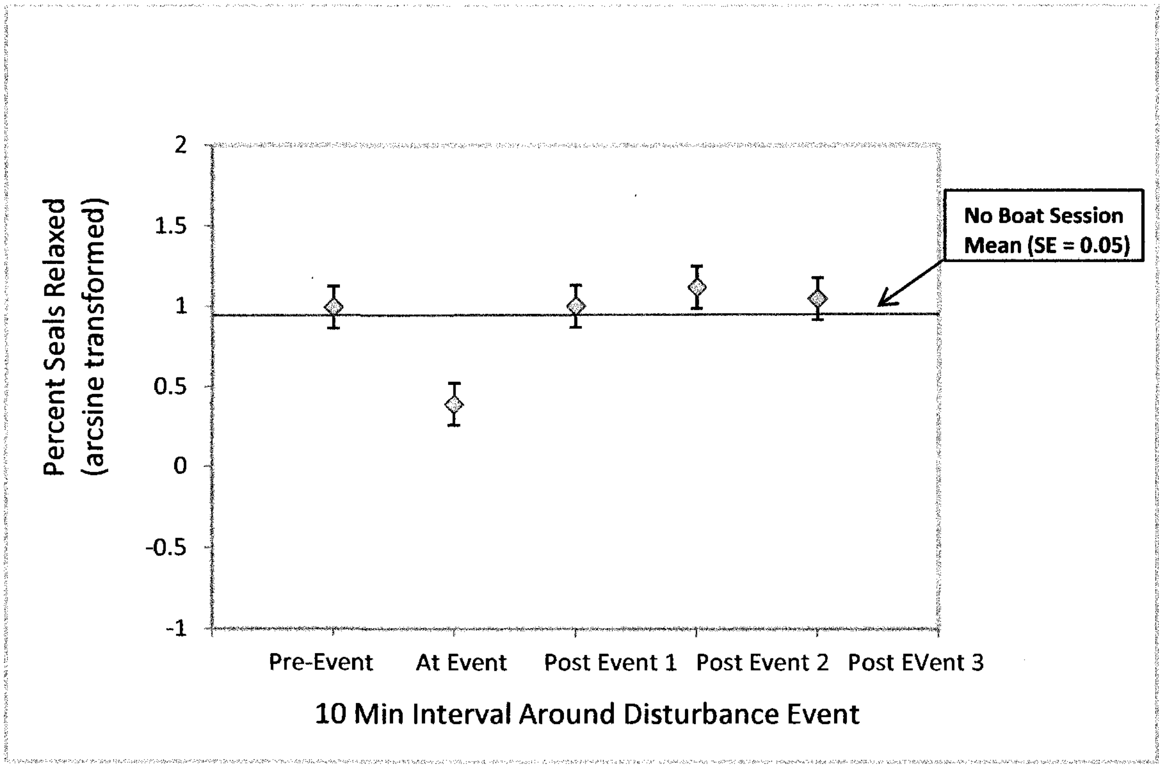


Figure 10. Percent seals relaxed, before, during, and after a first disturbance event.

Table 2: Post Hoc Analysis: First Event
(Tukey's Honestly-Significant Difference Test)

Percent Seals Relaxed	Mean Difference	P
Pre-Event vs. at Event	0.604	0.005
Pre-Event vs. 1st Period Post Event	-0.007	1.000
Pre-Event vs. 2nd Period Post Event	-0.125	0.944
Pre-Event vs. 3rd Period Post Event	-0.054	0.998
At Event vs. 1st Period Post Event	-0.612	0.005
At Event vs. 2nd Period Post Event	-0.730	0.001
At Event vs. 3rd Period Post Event	-0.658	0.004
1st Period Post Event vs. 2nd Period Post Event	-0.118	0.957
1st Period Post Event vs. 3rd Period Post Event	-0.046	0.999
2nd Period Post Event vs. 3rd Period Post Event	0.072	0.994

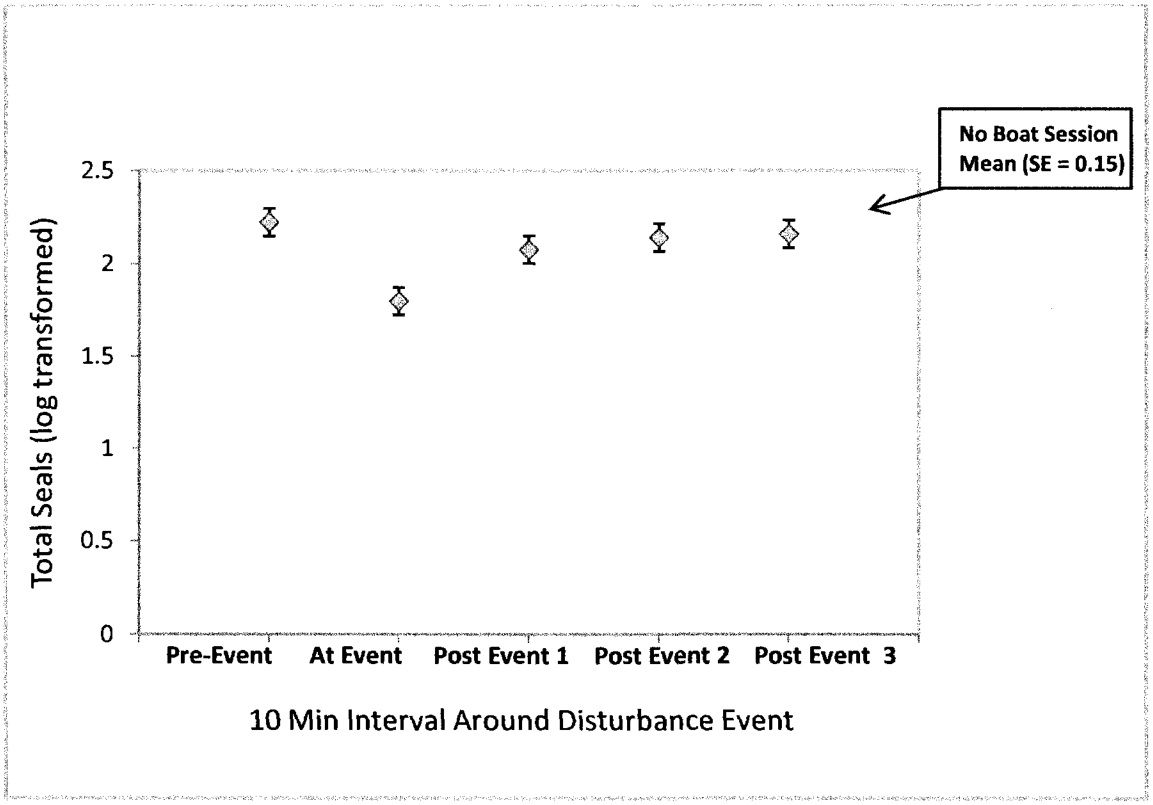


Figure 11. Total seals at haul-out before, during, and after a first disturbance event.

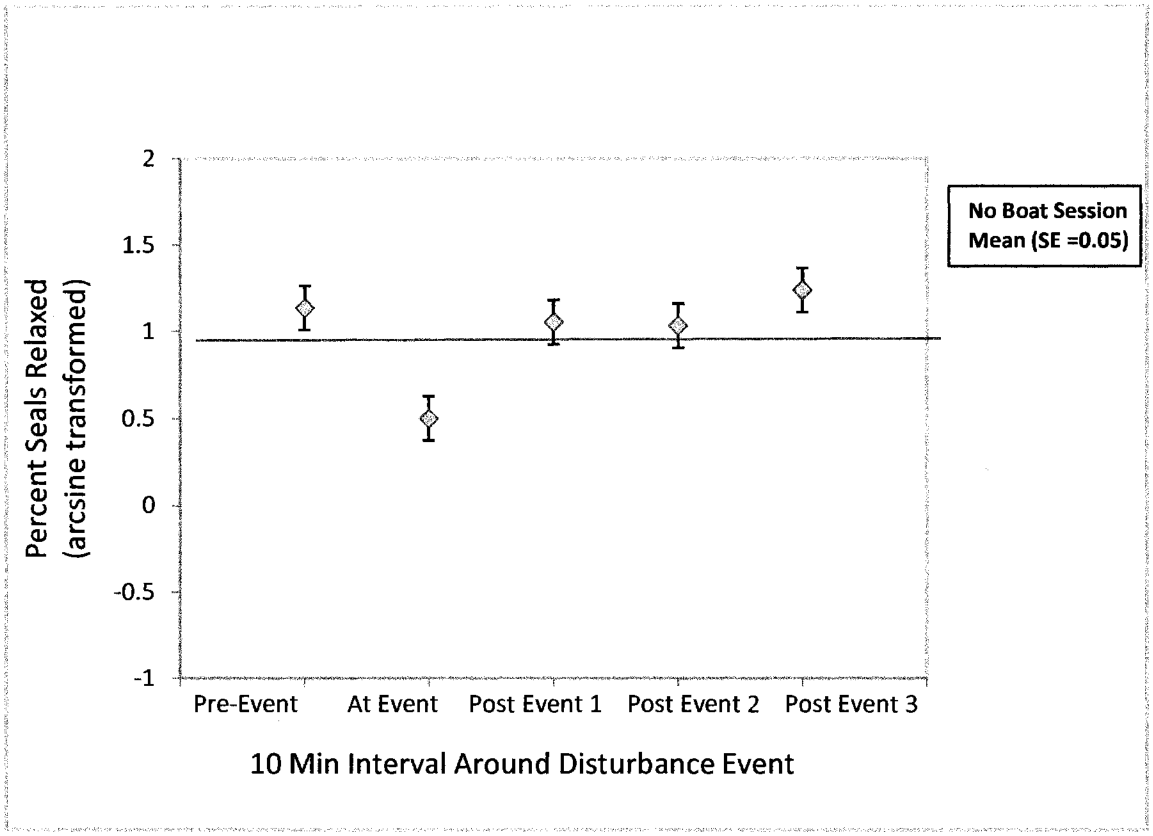


Figure 12. Percent seals relaxed before, during, and after multiple disturbance events.

Table 3: Post Hoc Analysis: Multiple Events
(Tukey's Honestly-Significant Difference Test)

Percent Seals Relaxed	Mean Difference	P
Pre-Event vs. at Event	0.636	0.000
Pre-Event vs. 1st Period Post Event	0.081	0.982
Pre-Event vs. 2nd Period Post Event	0.101	0.964
Pre-Event vs. 3rd Period Post Event	-0.101	0.965
At Event vs. 1st Period Post Event	-0.554	0.000
At Event vs. 2nd Period Post Event	-0.535	0.000
At Event vs. 3rd Period Post Event	-0.737	0.000
1st Period Post Event vs. 2nd Period Post Event	0.020	1.000
1st Period Post Event vs. 3rd Period Post Event	-0.183	0.768
2nd Period Post Event vs. 3rd Period Post Event	-0.202	0.712

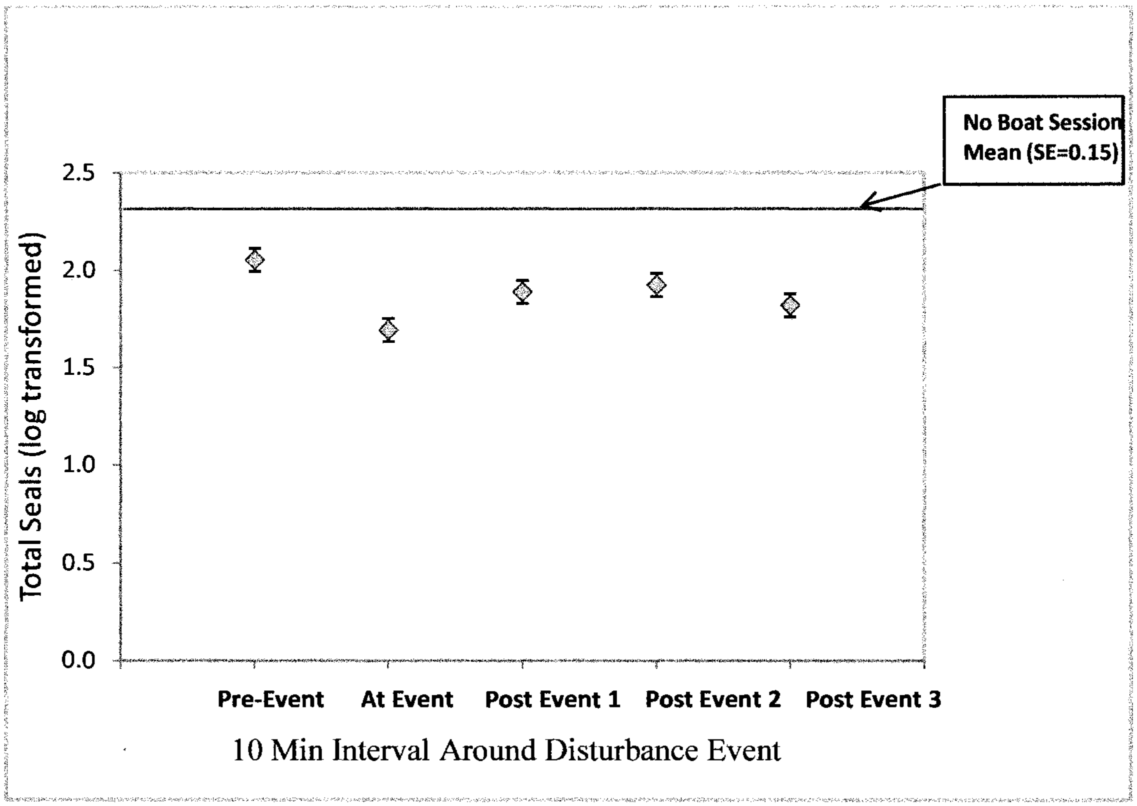


Figure 13. Total seals at haul-out before, during, and after multiple disturbance events.

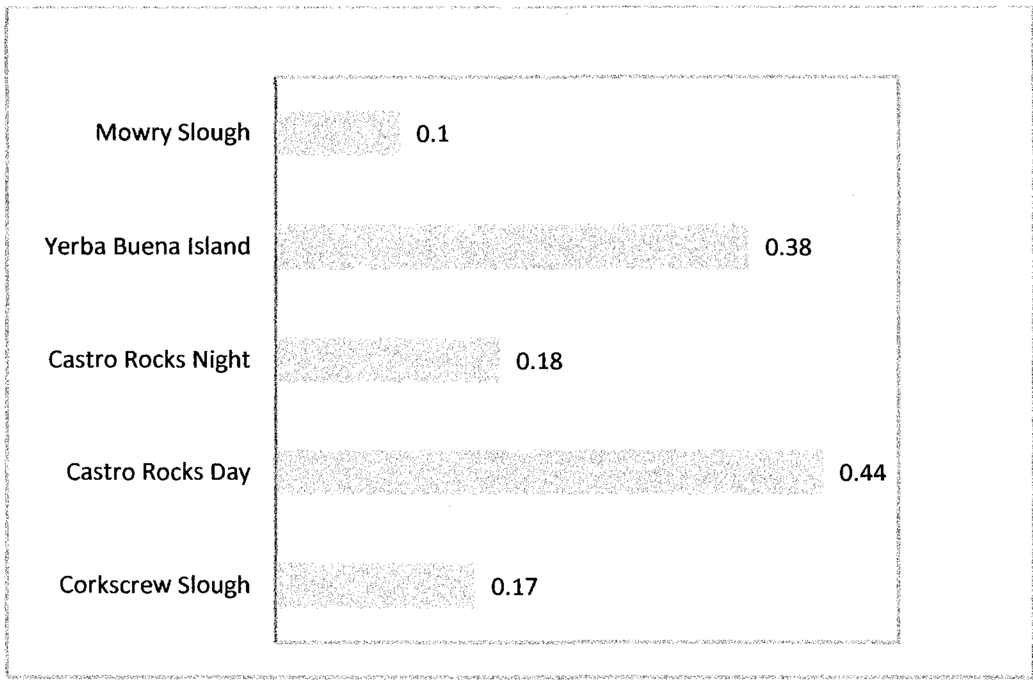


Figure 14. Flushes per hour caused by disturbance at various SF Bay haul-outs.

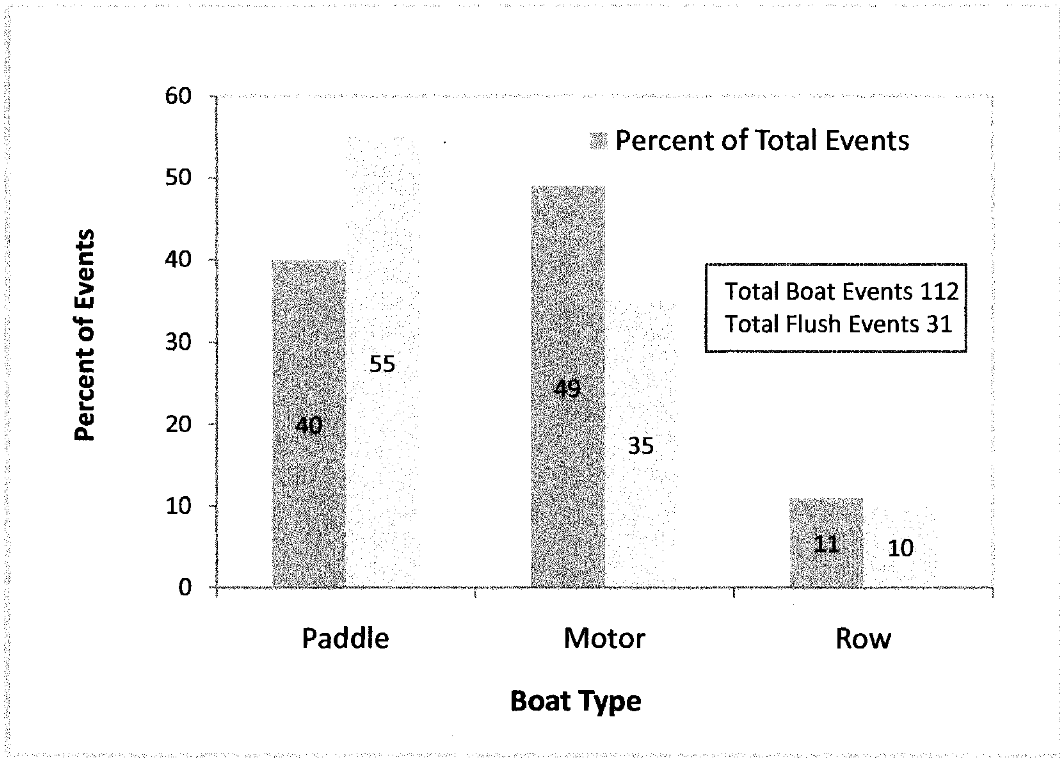


Figure 15. Boat types and percent flushes by type at Corkscrew Slough.

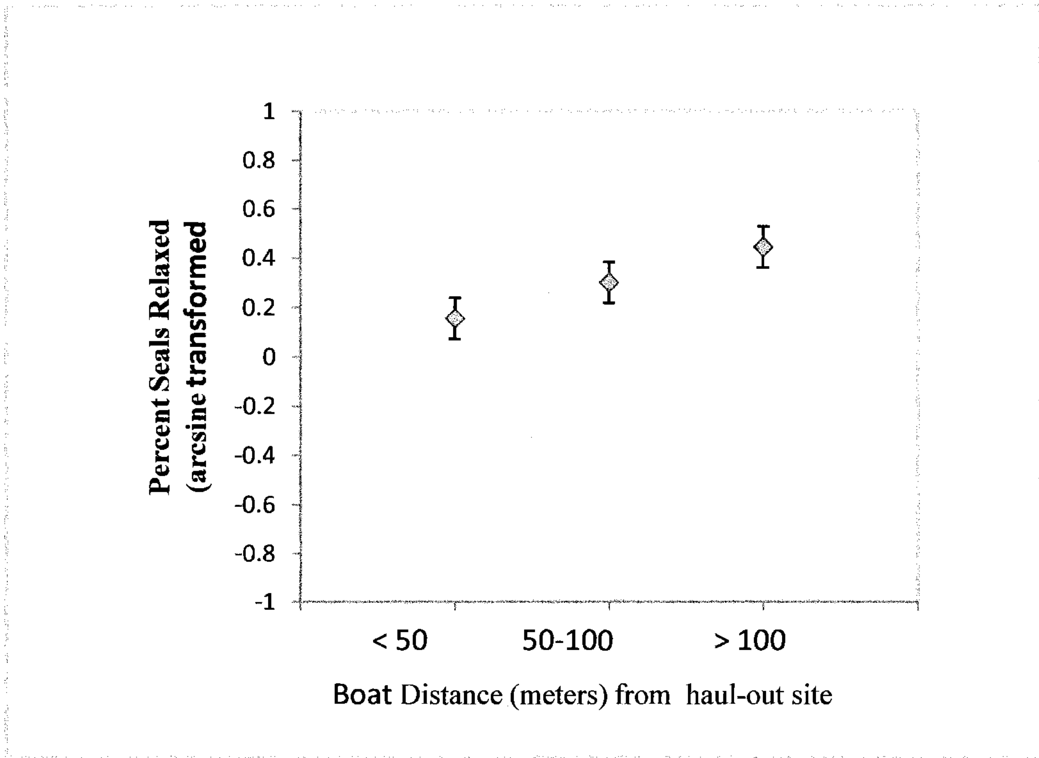


Figure 16. Percent seals relaxed as boats pass haul-out at varying distances.

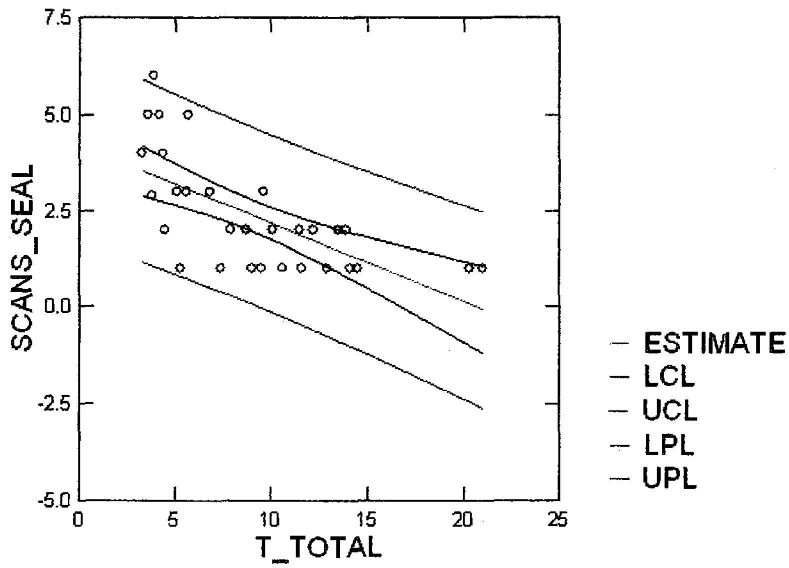


Figure 17. Average scans/seal versus total seals in sessions when boats were present.

Discussion

Population

Bair Island Refuge currently supports a breeding population of harbor seals that ranges from a few animals during the non-pupping season (August – February) to over 60 during the pupping season (March – July). This study's monthly observations and mean counts of 11 seals during non-pupping season and 42 during pupping season confirm that the site is utilized by seals year round. The last recorded census at Bair Island Reserve was conducted during 1991-1992 by Harvey and Kopec (1995) who reported maximum counts of 27 and 39 during the 1991-92 non-pupping season and maximum counts of 51 and 14 during pupping season. Prior to that time 1-12 seals were recorded during 1975-1976 [Risebrough et al. (1976)], and Fancher (1987) reported observing 1-5 seals at Corkscrew Slough during the late 1970s, one pup in May of 1980, and no seals during 1985 and 1986. Paulbitsky (1975) documented the earliest count of seals at Corkscrew Slough, which was 25 during spring in the 1950s.

Comparison of current and historical seal counts at Bair Island and in the South Bay in general is problematic because census data have been gathered infrequently and counting methods have varied. Fancher (1987) summarized counts he performed in the South Bay and [Risebrough et al. (1980)] summarized results of counts performed by various researchers. Typically, the data represent the maximum number of seals counted for multiple census dates at haul-out sites during the pupping or non-pupping season. Some data represent one-time aerial surveys for which only one count was performed. Seasons are defined differently by various researchers, but, at a minimum, pupping season includes April and May. In summary, between the 1950s when seals were first counted at Corkscrew Slough and 2007, the second year of this study, numbers ranged between zero and 25 seals. Outer Bair Counts which were taken between 1991 and 2007 ranged between 5 and 37 seals. The highest seal counts for the combined sites were 58 and 54 seals, obtained during the 2006 and 2007 pupping seasons, respectively.

While trend analysis is infeasible with such limited historical data obtained using different methods, it is worth reiterating that seals have been observed at Corkscrew Slough for the past 60 years, confirming this area as a long term stable haul-out site. Interestingly, the specific Corkscrew Slough haul-out areas observed during this study have changed since the counts performed by Kopec and Harvey (1995) in 1991 and 1992. During their study, seals were observed hauling out at the current CS1 and CS2 locations, but, in addition, seals were hauling out approximately 1800 m further into the slough at high tides. Seals were never observed hauling out at the distant location during the current study, although the researchers rafted that far on at least six occasions. Slough morphology has likely changed, which affects haul-out locations. The haul-out location observed at Outer Bair Island is the same one recorded by Kopec and Harvey (1995) for their 1991-1992 counts. According to Kopec (personal communication), hunters during the early 1990s first mentioned to the researchers that seals were hauling out at the remote site at Outer Bair Island, leading Kopec and Harvey to follow up with the original counts at that site. The proximity of the Outer Bair haul-out to the Bay and its remoteness in comparison to Corkscrew Slough may actually favor it as a haul-out habitat. Its shallow bathymetry limits access by seals during the lowest of tides but also limits boating activity. Corkscrew Slough provides relatively sequestered habitat that is accessible even at low tides, in spite of the fact that seals must access this area via Redwood Creek, an active shipping and recreational boating channel. During this study, seals were regularly observed swimming to and from Corkscrew Slough via Redwood Creek just as Trulio et al. (2003) observed. At high tide a borrow ditch connects Corkscrew Slough and Outer Bair haul-outs and it may possibly be used by seals. On one occasion, a mother and pup were observed swimming together in the borrow ditch. Individual seals were neither tagged nor marked for this study. Due to their similarity in color when wet, lack of sexual dimorphism, and infrequent obvious markings such as scars, it was not possible to identify individual seals on a regular basis. Therefore, it was not possible to determine whether individual seals haul out exclusively at Corkscrew Slough or Outer Bair or whether they use both sites at different times.

Five West Bay haul-out sites lie within close proximity to one another from the perspective of foraging ranges for harbor seals. The farthest distance between them lies between the entrance to Belmont Slough and the Ravenswood haul-out, a distance of approximately ten km. Seals are known to forage within ranges of 8 km on a regular basis (Harvey and Torok 1994, Allen et al 2006), so it would not be surprising to find that seals use more than one of these sites at different times depending perhaps upon tide levels, whether they have pups, and where the immediate fishing resources lie. From a wildlife management perspective, these haul-outs should be studied and protected collectively in order to maintain the optimal local habitat for harbor seals.

Seal count data obtained from this study, coupled with data describing current boating activity in Corkscrew Slough and seal response to boats, will assist future monitoring efforts to assess potential changes in boat traffic levels and the impact of those changes on the well-being of the seals at Bair Island Reserve.

Boating Activity

Three types of recreational boating, athletics, nature viewing, and motorized cruising represented the vast majority of activity in Corkscrew Slough. While fishermen and hunters passed through Corkscrew several times, fishing and hunting were never observed. A single agency boat from CA Dept of Fish & Game and the research raft accounted for the remainder of activity.

Athletic boaters appeared as solos or in groups and were clearly focused on rhythmic paddling as they traversed the slough without stopping or changing their momentum. Athletic paddlers in crews of 2-6 people per boat usually worked to paddle or row in tandem with one another and to achieve higher speeds. Sometimes coaches with megaphones would sit at the front of the boat and call out instructions to the crew. Athletic paddlers usually moved in a straight line down the middle of the waterway and thereby maintained a distance of at least 50 meters from the seals at CS1 and greater than 100 meters from seals at CS2. Athletes passed the haul-outs quickly, oriented parallel to the shore and were not observed to turn their heads or boats toward the seals, rather their attention was focused upon their own activity.

Nature viewers tended to travel at slower speeds, somewhat closer to shore and to orient their heads, although not necessarily their boats, directly toward the seals as they passed the haul-out site. While they usually traversed the slough in a straight line, they were more apt to change the angle of their boats with respect to shore and to change their speed, sometimes slowing down to drift past the haul-out or even lingering in place close to the haul-out site. On one occasion four nature viewers stopped their two kayaks within 30 meters of the haul-out by holding the tips of their paddles against the bank as they watched the seals. This action resulted in all 14 seals at the haul-out flushing into the water.

Motorized cruisers tended to move directly through the slough, usually down the middle of the waterway where the depth was greatest. Cruisers often directed their heads to look at the seals, sometimes using binoculars and on occasion would slow down as they past the seals. Cruisers generally oriented their boats parallel to the shore.

Observations regarding the varying behaviors of recreationists in this study are consistent with Klein's (1993) observation that the behavior of recreationists can have a profound influence on wildlife responses and should be studied in more detail. For example some researchers have found that looking at or approaching wildlife is more likely to cause disturbance than is tangential approach (Burger and Gochfeld, 1981). Allen et al (2006) observed that watercraft disturbances near the Richmond Bridge in San Francisco Bay were most likely caused by boats moving at varying speeds, changing course and remaining within close proximity to the haul-out site. Suryan and Harvey

(1999) reported that most harassments in their study in the San Juan Islands of Washington State were caused by boaters approaching haul-outs to view the seals. For birds faster and louder boats cause greater disturbance, however motor boats did not have the same effect for seals at Corkscrew Slough.

Boating activity was reasonably constant all year round due in part to the Bay area's mild climate and the year round activities scheduled by local boating organizations. Traffic levels were nearly double on weekends versus week days (0.64 boats per hour versus 0.38 boats per hour).

With respect to the total daytime hours that seals spent at the haul-out, the amount of time they actually encountered boats was small. Overall, a total of 0.55 boats events occurred per hour and as the average time boats took to pass the haul-out was approximately 1 minute, seals encountered boats less than 1% of the time. When other events disturbing seals, including airplanes, birds, other seals and researchers are added, seals encountered some form of disturbance at a rate of 0.76 disturbances per hour or 1.3% of daylight hours.

In comparison, seals at Castro Rocks and Yerba Buena Island haul-outs (which were monitored for disturbances during a seven year period in conjunction with the earthquake retrofit of the Richmond –San Rafael Bridge), encountered disturbances of all types at a rate of 3.22 and 6.21 disturbances per hour. Castro Rocks disturbances included bridge-related construction activities (2.35 per hour). Disturbances that caused seals to flush occurred at a rate of 0.44 per hour at Castro Rocks and 0.38 per hour at

Yerba Buena Island compared to .17 per hour at Corkscrew Slough (excluding research raft events) (Figure 15). Corkscrew Slough's relatively flush rate compares favorably with Mowry Slough, the South Bay's most populated haul-out site, which demonstrated a rate of 0.1 flushes per hour (Figure 15). Thus, current levels of boating disturbance are quite low.

Researchers walking on land caused significant disturbances to seals at the CS1 haul-out site. It was not possible for researchers to access the CS1 and CS2 observation points without being seen by the seals. In spite of researchers moving slowly and in a bent over position seals would become alert and frequently flush upon seeing them. Seals that flushed at CS1 would often follow in parallel as the researcher(s) continued on to the CS2 observation point and then would either swim back to the CS1 haul-out and recover there or swim on and haul-out along CS2. The significant impact of people walking on land has strong management implications. Currently public land access at the Reserve is expressly forbidden. This study demonstrates why that policy is beneficial for harbor seals.

Seal Behavioral Response to Boats

The behavioral response of seals to boats passing the Corkscrew Slough haul-out was generally subdued. There was no difference in overall baseline vigilance levels or in total number of seals at the haul-out sites during sessions when boats were present versus when they were absent. Nevertheless, seals definitely responded to boats as they moved past the haul-out site. Levels of relaxation and total numbers of seals dropped significantly during the first boating event of a session, but they recovered within 10 minutes of the boat's passing (Figure 11). Pre-event and 10-minute post-event means were comparable to the mean percent of relaxed seals during sessions when no boats were present, a baseline activity measure, (Table1), thus confirming the lack of long-term response.

Interestingly, results for multiple events sessions differed from those for first event sessions. During multiple event sessions, seal relaxation also dropped significantly as boats passed the haul-out, but seal relaxation levels before and after the event were higher than the mean during no-boat sessions (Figure 13). This higher level of relaxation may be due to the fact that total numbers of seals during multiple event sessions were lower overall than no event sessions (Figure 14). It may be that when there are multiple boating events seals that are less tolerant of boats leave the haul-out site and those who remain are more relaxed because they are more tolerant of boats. Suryan and Harvey (1999) describe the same pattern by seals in the San Juan Islands of Washington State. In their study, seals that remained on shore or returned to shore after flushing due to disturbance by powerboats, subsequently tolerated boat approaches at significantly closer distances, demonstrating they were less easily disturbed.

At Corkscrew Slough seals responded differently to different boat types. While paddle boats represented only 40% of total boat events, they were the cause of 55% of flush events, a disproportionate amount. Motor boats, in comparison, represented 49% of total events, but caused only 35% of flush events. Row boats caused 10% of flush events, while they represented 11% of total boat events (Figure 16). Two other studies report results consistent with the current study. Calambokidis et al. (1991) found harbor seals were harassed by kayaks at greater distances than powerboats and Suryan and Harvey (1999) found 55% of kayakers within 1 km of a haul-out caused seals to flush versus 9% of powerboats in the same distance category. Allen et al. (1984) found that distance from the disturbance rather than type of disturbance most impacted the degree of seal response. Seals at Corkscrew Slough did not flush at significantly higher rates according to distance of boats from the haul-out. However, seal vigilance increased as boats passed closer to the haul-out site (Figure 16).

Several factors may help to explain the more muted response of seals to motor boats than to paddle boats at Corkscrew Slough. First, due to the winding nature of the slough and the fact that seals tend to cluster around its bends at CS1 and CS2, paddlers quietly approaching the CS1 haul-out from Redwood Creek or the CS2 haul-out from Steinberger Slough, would be more likely to surprise the seals than would motor boats, which can always be heard from a distance. Seals were, in fact, observed to orient their heads in the direction of oncoming motor boats before the boats were visible. On one occasion, a group of 14 relaxed seals at CS2 was observed becoming more alert, with increasing numbers of seals raising their heads and orienting them towards the West. Within about 30 seconds a singing kayaker came around the bend and paddled past the haul-out site. All 14 seals remained alert, but none move toward the water or flushed. In conversation later at the launch site, the kayaker explained he has sung to the seals for years in advance of passing the haul-out and has found that they don't appeared to be bothered by his presence (personal communication). Bonner (1982) reports similar observations with seals off the English coast that became accustomed to regular tourist boats and remained at the haul-out as they passed, but flushed in response to strange vessels. Bonner (1982) posits that the seals recognized the sound of the tourist boat engines. Variability reduces predictability, from the harbor seal's point of view. As Knight and Cole (1995) state, predictability is an important factor with respect to wildlife response to disturbance. "When animals perceive a disturbance as frequent enough to be "expected" and nonthreatening they will show little overt response". The ability of seals to hear oncoming motor boats at Corkscrew Slough improves the predictability and potentially reduces the perceived threat of this type of disturbance.

Seals in this study did not show a significant response to varying numbers of boats or boaters in groups passing the haul-out, or to boater noise or behavior. Perhaps these characteristics were less important to the seals or were not differentiated by the seals. Researcher observations also showed little variability in boater noise or behavior. There were no incidents of humans intentionally harassing the seals. With the exception of several groups of nature viewers who lingered in the water near the site and one group touching their kayaks to shore in order to remain in a steady position, no recreational boaters approached the seals at close range. Additionally, nature viewers were observed to minimize their movement and to remain quiet as they watched the seals.

Overall, seals did not respond differentially to boat speed or noise, except during one extreme event. One of the most significant disturbances observed during the course of the study was an extremely loud and fast airboat which passed CS1, creating significant wave action upon shore. All seals flushed in response to this event and approximately 30 minutes passed before seals returned to shore. Similarly, researchers on land caused significant disturbance to the seals as they approached the haul-out site, resulting in frequent flushing by at least some of the hauled out seals. Interestingly, after flushing from the CS1 haul out in response to passing researchers, seals would frequently swim along with the researchers towards CS2 and after researchers sat in place, would swim on and re-haul out at CS2.

Habituation

Seals at Corkscrew Slough appeared to demonstrate habituation to boaters passing the haul-out site. Some or all of the seals remain hauled-out during 70% of boating events and seals return to or near to the haul-out following flush events. This behavior suggests that at current boating levels, seals have become accustomed to recreationists passing the haul-out site.

The bathymetry of Corkscrew Slough includes sloped banks that allow seals easy access to the water and water depths sufficient for swimming even at the lowest of tides. These characteristics coupled with Corkscrew Slough's wide expanse, probably contribute to the seals' ability to cope with boating disturbance. When seals do become threatened enough by boats to flush into the water, they are often spend some time swimming in the open waters of the slough and then eventually re-haul to their original haul-out spot or to another one along the slough.

Seals also demonstrated active curiosity towards humans at Corkscrew Slough. During the course of this study, swimming seals would commonly follow the research raft from a distance of 10 – 20 meters, closely watching the researchers and intentionally making eye contact with them. Such behavior was even demonstrated by mothers and pups. In addition, even after flushing from the CS1 haul-out site in response to walking researchers, some of the seals would swim along the slough in parallel with walking researchers as they approached their CS2 observation points, only to swim off as the researchers became seated in the marsh. This observed level of curiosity and attraction toward humans suggests that some habituation has taken place for at least some of the seals at Corkscrew Slough.

Seals at the remote Outer Bair haul-out demonstrated strong disturbance responses to researchers in the research raft. Some or all of the haul-out seals flushed as the research raft motored past over 50% of the time. During ground based observations seals were unaware of the researchers, except on one occasion when a standing researcher was noticed and all of the seals flushed in response. Seals at Outer Bair may be more alarmed by passing boats due to the narrow width of the waterway which brings boats within 30 meters of the shore and due to the relative infrequency of such encounters at this haul-out site.

Conclusions

Bair Island Refuge protects prime haul-out habitat for harbor seals in the South San Francisco Bay, supporting a population of at least 60 harbor seals during the pupping/molting season. While the existing historical data are too scant for population trend analysis, it is clear that seals have been hauling out in Corkscrew Slough for the past 60 years, demonstrating the type of site fidelity they have shown in other locations.

Seals rarely encounter recreational boaters at the remote Outer Bair haul-out, but they do encounter a variety of boats within Corkscrew Slough on a year round basis. Current traffic levels average 0.55 boats per hour through Corkscrew Slough. Such levels are considerably lower than those at some other haul-out sites in the San Francisco Bay, although they are higher than levels at the very sequestered Mowry Slough haul-out. Recreational boaters used Corkscrew Slough on a year round basis, mostly as solo boaters or in small groups of 2 – 6 boats. On occasion, large organized events bring significantly more traffic through the slough for a short period of time. Thirty seven kayak and outriggers and a supporting group of two motor boats moved by the Corkscrew haul-out area within a 30 - 45 minute period during an organized race in February 2007.

Seals appear tolerant of recreational boaters at current traffic levels. They remained at the haul-out without flushing during 70% of boating events and when seals did flush they almost always recovered within the large Corkscrew Slough haul-out area. The bathymetry, length, winding nature and sloping shoreline at Corkscrew Slough may contribute to the seals' ability to cope with boats that pass. When seals become alarmed, escape to the water is easy; the wide body of water allows for extended periods of swimming, and the long expanse of the slough allows many alternatives for hauling out. Humans walking on the marsh plain near the haul-out site cause severe disruption to the seals as do extremely loud and fast boats that create an extreme wake as they pass.

While seals appear generally tolerant of boaters at current traffic levels, total seal numbers at the haul-out were lower during multiple boat sessions than the baseline observed during no boat sessions. These data demonstrate a longer term impact from multiple boat events than for a single boat event, suggesting that more boat traffic may reduce the number of seals using Corkscrew Slough. Currently, multiple event sessions are not common enough to result in statistically lower numbers on days with boats versus days without. Increases in boating at Corkscrew Slough and seal responses should be monitored regularly in order to assess the potential impact.

Recommendations

Current management efforts to protect the haul-out sites at Bair Island Refuge should be continued. Most specifically, land access either by people on foot or by boats landing on shore should remain expressly forbidden. Larger, more visible "No Trespassing" signs should be mounted along the waterway at Corkscrew Slough and on the Outer Bair peninsula adjacent to the haul-out site, where trash and empty gun shells indicate trespassing has occurred. In addition, interpretive signs posted at the public launch ramp could inform recreationists of what types of wildlife they might see along the waterways at Bair Island and what actions they can take in order to minimize their impacts.

Public outreach efforts teaching recreational boaters the rules of "wildlife" etiquette should continue. The current USFWS website has an excellent description of harbor seals and recommendations for viewing them without provoking disturbance. The same type of information could be added to other recreational and environmental websites that reach outdoor enthusiasts in the San Francisco Bay area.

Additional harbor seal census data should be gathered on an annual basis at all of the haul-out sites along the western shore of the South Bay in order to get a more complete picture of currently useable habitat. It would be helpful to know if other historical haul-outs including Belmont Slough, Ravenswood Point, and Greco Island currently support seals or if those habitats have been degraded.

Boating traffic and seal behavioral responses should continue to be monitored at Bair Island Reserve. The data collected for this study can provide baseline information to compare with future seal behavior should boating traffic increase. If increased traffic does occur and causes reduction in seal numbers or increases in flush rates action may need to be taken to limit boating levels.

Future studies could be designed to improve our understanding of how recreational boaters and seals can co-exist in the seals' habitat. A study designed to specifically test seal response to boats at various distances, angles of orientation and changing speeds would be of interest. Comparison of the level of habituation seals demonstrate at various haul-out sites such as Elkhorn Slough, Corkscrew Slough, Mowry Slough and the Central Bay might also shed light on differences that make some haul-out sites more compatible to recreational boating than others.

References

Alcorn, D.J. and L.E. Fancher 1980. Report on harbor seals of the San Francisco Bay National Wildlife Refuge South San Francisco Bay, California. Final Report to USFWS, SFBNWR. 80, April 1980.

Allen, S.G. 1991. Harbor seal habitat restoration at Strawberry Spit, San Francisco Bay. Marine Mammal Comm., Contract MM291 0890-9 Nat'l Tech. Information. Service., Alexandria, VA.

Allen, S.G, D.G. Ainley, G.W. Page, and C.A. Ribic 1984. The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, CA. *Fishery Bulletin*: Vol. 82(3): 493-500.

Allen, S. and H Markowitz, 2006. Monitoring the potential impact of the seismic retrofit construction activities at the Richmond-San Rafael Bridge on harbor seals (Phoca vitulina richardsi): May 1998-September 15, 2005. Final Report to the California Department of Transportation. Contract 04A0628.

Allen S.G., M. Stephenson, R.W. Risebrough, L. Fancher, A. Shiller, and D. Smith 1993. Red-pelaged harbor seals of the San Francisco Bay Region. *Journal of Mammology* 74(3):588-593.

Andersen, R., J.D.C. Linnell, and R. Langvantn 1996. Short term behavioral and physiological response of moose (Alces alces) to military disturbance in Norway. *Biological Conservation* 77, pp 169-176.

Bartholomew, G.A., Jr. 1949. A census of harbor seals in San Francisco Bay. *Journal of Mammalogy* 30:34-35.

Belanger, L. and J. Bedard 1989. Responses of staging greater snow geese to human disturbance. *Journal of Wildlife Management* 53, pp. 713-719.

Berger T.L. 1996-2001. Pinnipeds of the Northern California Coast. Retrieved September, 2008 from http://clone. spore.org/ picori/pinni ped/phoc.html.

Bonner, W.N. (1982) Seals and man: a study of interactions. Seattle, WA.University of Washington Press.

Boyle, S.A. and F.B. Samson. 1985. Effects of non-consumptive recreation on wildlife: a review. *Wildlife Society Bulletin* 12:110-116.

Buckingham, C.A., L.W. Lefebvre, J.M. Schaefer, and H.I. Kochman 1999. Manatee response to boating activity in a thermal refuge. *Wildlife Society Bulletin* 27 (2): 514-522 SUM 1999.

Burger J. 1981. The effect of human activity on birds at a coastal bay. *Biological Conservation* 21:231-241.

Burger, J. M. Gochfeld, and L.J. Niles. 1995. Ecotourism and birds in coastal New Jersey: contrasting responses of birds, tourists, and managers. *Environmental Conservation* 22:56-65.

Calambokidis, J., G.H. Steiger, J.R. Evenson and S.J. Jeffries. 1991. Censuses and Disturbance of harbor seals at Woodard Bay and recommendations for protection. Final report to the Washington Department of Natural Resources, Olympia, WA.

Carney, K. M., and W. Sydeman. 1999. A review of human disturbance effects on colonial waterbirds. *Colonial Waterbirds* 22: 68-79.

Cole, D.N. and P.B. Landres. 1995. Indirect effects of recreation on wildlife. In R. Knight and K. Gutzwiller, Ed. *Wildlife and Recreationists: Coexistence through Management and Research* (pp. 183-201). Washington, DC: Island Press.

Connor R.C. and Smolker 1985. Habituated Dolphins (Tursiops Sp.) in Western Australia. *Journal of Mammology*, 66(2): .398-400.

Constantine R., D.H. Brunton, and T. Dennis, 2004. Dolphin-watching tour boats change bottlenose dolphin (Tursiops truncatus) behavior. *Biological Conservation* 117(3):299-307.

Cooke, A.S. 1980. Observations on how close certain passerine species will tolerate an approaching human in rural and suburban areas. *Biological Conservation* 18:85-88.

Cordell H.K., J. Teasley, G Super, J.C. Bergstrom, and B McDonald 1997. Outdoor recreation in the United States: results from the national survey on recreation and the environment. A report for USDA Forest Service Recreation Managers and Planners.

Da Silva, J. and J.M. Terhune. 1988 Harbor seal grouping as an anti-predator strategy. *Animal Behaviour* 36(9): 1309-16.

Deutsch, C.J., J.P. Reid, R.K. Bonde, D.E. Easton, H.I. Kochman, and T.J. O'Shea 2003. Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic Coast of the United States. *Wildlife Monographs* 151: 1-77.

Eibl-Eibesfeldt, I. 1970. E*thology:The Biology of Behavior.* New York: Holt, Rinehart, and Winston. 530 pp.

Engelhard, G.H., A. Baarspul, M. Broekman, J.C.S. Creuwels, P.J.H. Reijnders 2002. Human disturbance, nursing behavior, and lactational pup growth in a declining southern elephant seal (*Mirounga leonine*) population. *Canadian Journal of* Zoology. 80(11): 1876-1886.

Fancher, L. 1979. The distribution, population dynamics, and behavior of the harbor seal, *(Phoca vitulina richardsi)* in South San Francisco Bay, California. M.S. Thesis, California State Univ., Hayward, CA 109 pp.

Fancher, L. 1987. An update on the current status of the harbor seal in San Francisco Bay. San Francisco, CA. Bay Institute of San Francisco. 9 pp.

Freddy, D.J., W.B. Bronaugh, and M.C. Fowler. 1986 Response of mule deer to disturbance by persons at foot and snowmobiles. *Wildlife Society Bulletin* 14:63-68.

Frid, A. and L.M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6(1):11.

Gabrielsen, G.W. 1985. *Do* not disturb nesting eiders! *Norsk Polarinstitutt Arbok* 1984, 21-24.

Gabrielsen, G.W. and E.N. Smith. 1985. Physiological responses associated with feigned death in the American opossum. *Acta Physiologica Scandinavia* 123:393-398.

Galloway, M.J. 2000. Factors Influencing Scanning Rates of Harbor Seals at Yerba Buena Island, California. M.S. thesis. California State University San Francisco, CA 90 pp.

Gill, J.A., K. Norris, and W.J. Sutherland 2001. Why behavioral responses may not reflect the population consequences of human disturbance. *Biological Conservation* 97:265-268.

Gill, J.A., J. W. Sutherland, and A.R. Watkinson. 2001. A method to quantify the effects of human disturbance on animal populations. *Journal of Applied Eco*logy 33 (8):786-92.

Glockner-Ferrari, D.A., and M.J. Ferrari, 1995. Individual identification, behavior, reproduction, and distribution of humpback whales, (*Megaptera novaeangliae)*, in Hawaii. Rep MMC-83/06 for Mrine Mammal Commision, 42 p. (NTIS PB85-200772).

Goals Project. 2000. Baylands Ecosystem Species and Community Profiles. A report of life histories and environmental requirements of key plants, fish and wildlife. San Francisco: U.S. Environmental Protection Agency, S.F. Bay Regional Water Quality Control Board.

Grigg, E.K., A.G. Allen, D.E. Green, H. Markowitz 2004. Harbor Seal (*Phoca vitulina richardsi*) population trends in the San Francisco Bay Estuary, 1970-2002. *California Fish and Game Journal* 90(2): 51-70.

Harvey, J.T. and M.L. Torok. 1994. Movements, dive behaviors and food habits of harbor seals (*Phoca vitulina richardsi*) in San Francisco Bay, California. Appendix (dated March 1994; 92pp.) to A.D. Kopec and J.T. Harvey. 1995. *Toxic pollutants, health indices and population dynamics of harbor seals in San Francisco Bay,* 1989-1992. Moss Landing Marine Laboratories Technical Pub. 96-4, Moss Landing, CA.

Hicks, L.L. and J.M. Elder. 1979. Human disturbance of Sierra Nevada bighorn sheep. *Journal of Wildlife Management* 43:909-915.

Hill, D., D. Hockin, D. Price, G. Tucker, R. Morris, and J. Treweek. 1997. Bird disturbance: improving the quality and utility of disturbance research. *Journal of Applied Ecology 34:275-288.*

Hulbert,S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monograph* 54:187-211.

Jelinski, D.E., C.C. Krueger, and D.A. Duffus 2002. Geostatistical analyses of interactions between killer whales (Orcinus orca) and recreational whale-watching boats. *Applied Geography* 22(4): 393-411.

Johnson, S.R., J.J. Burns, C.I. Malme, and R.A. Davis 1989. Synthesis of information on the effects of noise and disturbance on major haulout concentrations of Bering sea pinnipeds. LGL Alaska Research Associates Report MMS 88-0092.

King, Judith 1983. *Seals of the World.* Cornell University Press, New York.

King, J.M., and J.T. Heinen 2004. An assessment of the behaviors of overwintering manatees as influenced by interactions with tourists at two sites in central Florida. *Biological Conservation* 117 (3): 227-234.

Klein, M.L. 1993. Waterbird behavioral responses to human disturbances. *Wildlife Society Bulletin* 21:31-39.

Klein, M.L., S.R. Humphrey, and H.F. Percival, 1995. Effects of ecotourism on distribution of water birds in a wildlife refuge. *Conservation Biology* 9, pp 1454-1465.

Kloppers, E.L., C.C. St. Clair, and T.E. Hurd, 2005. Predator-resembling aversive conditioning for managing habituated wildlife. Ecology and Society 10(1):31.

Knight, R.L. and D.N. Cole. 1995. Wildlife responses to recreationists. Pp51-69 in R. Knight and K. Gutzwiller, ed. *Wildlife and Recreationists: Coexistence Through Management and Research.* Island Press, Washington, D.C. 372 pp.

Kopec, A.D. 1999. Harbor seals in the bay. *Tideline* 19(1):1-3.

Kopec, *A.D.* and J.T. Harvey. 1995, Toxic pollutants, health indices and population dynamics of harbor seals in San Francisco Bay, 1989-1992. Moss Landing Marine Laboratories Technical Pub. 96-4, Moss Landing, CA. 138 pp.

Lafferty, K.d., D. Goodman, and C.P. Sandoval 2006. Restoration of breeding by snowy plovers following protection from disturbance. B*iodiversity and Conservation* 15:2217-2230.

Madsen, J. and A.D. Fox, 1995. Impacts of hunting disturbance on water birds-a review. *Wildlife Biology* 1:193-207.

Mattson, D.J. and M.M. Reid 1991. Conservation of the Yellowstone grizzly bear. *Conservation Biology* 5(3) 364-372.

National Marine Fisheries Service Northwest Fisheries Science Center and National Marine Fisheries Service Northwest Region, 1997. Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of WA, OR, and CA. US. Dept Commerce/NOAA/NMFS/NWFSC/Publications.

National Marine Fisheries Service *Draft Interim Report to NOAA Fisheries/NMFS,* April 2001. Retrieved September, 2008 from @ http://online.sfsu.edu/ halmark/tagging.htm.

Newby, T.C. 1978. Pacific harbor seal in marine mammals of Eastern North Pacific and Arctic waters. Ed. D. Haley. Pacific Search Press, Seattle, WA.

Orams, M.B. 2002. Feeding wildlife as a tourism attraction: a review of issues and impacts. *Tourism Management* 23(3): 281-293.

Orr R.T. and Helm R.C. 1989. Marine mammals of California. University of California Press, Berkeley, CA.

Paulbitsky, P. 1975. The seals of Strawberry Spit. *Pacific Discovery* 28: 12-15.

Paulbitsky, P. 1976. Unpublished field notes. Referenced in Kopec, *A.D.* and J.T. Harvey. 1995, Toxic pollutants, health indices and population dynamics of harbor seals in San Francisco Bay, 1989-1992. Moss Landing Marine Laboratories Technical Pub. 96-4, Moss Landing, CA. 138 pp.

Pfister, C., B.A. Harrington and M. Lavine 1992. The impact of human disturbance on shorebirds at a migration staging area. *Biological Conservation* 60, pp. 115-126.

Renouf, D., L. Gaborko, G. Galway, and R. Finlayson. 1981. The effect of disturbance on the daily movements of harbour seals and grey seals between the sea and their hauling grounds at Miquelon. *Applied Animal Ethology* 7:373-379.

Reynolds, P.C. and D. Braithwaite 2001. Towards a conceptual framework for wildlife tourism. *Tourism Management* 22(1):31-42.

Ridgeway, S.H. 1972. Mammals of the sea: biology and medicine, ed S.H. Ridgeway, 170 - 173. Springfield, Ill: Charles C. Thomas.

Riedman, Marianne, 1990. The pinnipeds: seals, sea lions, and walruses. University of California Press, Berkeley, CA.

Richmond Bridge Harbor Seal Survey Summary, 2003. Retrieved July, 2008 from http://online.sfsu.edu/ halmark/proj sum.htm.

Risebrough, R.W., D. Alcorn, S. Allen, V. Anderlini, L. Boorien, R. Delong, L. Fancher, R. Jones, S. McGinnis, and T. Schmidt, 1980. Population biology of harbor seals in San Francisco Bay, California. Report of the Bodega Bay Institutie of Pollution Ecology to the Marine Mammal Commission, reproduced by U.S. Department of Commerce, National Technical Info Service, MMC-76/19, 66 pp.

Rodgers, J.A., and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. *Conservation Biology* 9:89-99.

Salden, D.R. 1988. Humback whale encounter rates offshore of Maui, Hawaii. *Journal of Wildlife Management* 52(2):301-304.

Scheer, M., B., Hofmann, and I.P. Behr 2004. Ethogram of selected behaviors initiated by free-ranging short finned pilot whales (*Globicephala macrorhynchus*) and directed to human swimmers during open water encounters. *Anthrozoos* 17(3):244-258.

Soloman, Jay 2005. Gentle Giants of Baja – Tour of coastal waters gets up close and personal with whales, Argus Newspaper, Sunday 11/13/2005.

Stein, J.L. 1989. Reproductive Parameters and Behavior of Mother and Pup Harbor Seals, *Phoca vitulina richardsi*, in Grays Harbor, Washington. M.S. Thesis, San Francisco State University, San Francisco, CA 110p.

Stienstra, T. 2005. Elkhorn Slough provides an exciting wildlife show. Retrieved November, 2008 from http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2005/11/06/SPGCEFJV5H1.DTL.

Stockwell, C A., G.C. Bateman, and J. Berger, 1991. Conflicts in national parks: a case study of helicopters and bighorn sheep time budgets at the Grand Canyon. *Biological Conservation* 56:317-328.

Suryan, R.M., and J.T. Harvey. 1999. Variability in reactions of Pacific harbor seals, *Phoca vitulina richardsi*, to disturbance. *Fishery Bulletin* 97, no.2: 332-9.

Terhune, J.M. 1985. Scanning Behavior of Harbor Seals on Haul-Out Sites. *Journal of Mammalogy*, 66(2):392-305.

Terhune, J.M. and S. W. Brillant. 1996. Harbour seal vigilance decreases over time since haul out. *Animal Behavior* 51 (April): 757-63.

Titus, J.R. and L.W. VanDruff. 1981. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. *Wildlife Monograph* 79:1-58.

Thompson, M.J. and R.E. Henderson 1998. Elk habituation as a credibility challenge for wildlife professionals. *Wildlife Society Bulletin* 26 (3): 477-483. Fall 1998.

Torok, M.L. 1994. Movements, Activity Patterns, Dive Behavior, and Food Habits of Harbor Seals *(Phoca vitulina richardsi)* in San Francisco Bay, California. M.S.Thesis California State University, Stanislaus. 88 pp.

Trulio, L. 2003. An Observational Study of Harbor Seal Activity and Boat Traffic near Corkscrew Slough at Bair Island. Unpublished. Submitted to Clyde Morris, Refuge Manager Don Edwards national Wildlife Refuge, U.S. Fish & Wildlife Service.

Trulio, L. 2005. Understanding the Effects of Public Access and Recreation on Wildlife and their Habitats in the Restoration Project Area. Report for South Bay Salt Pond Project. http://www.southbayrestoration.org/Documents.html.

Tyler, N.J.C. 1991. Short-term behavioral responses of Svalbard reindeer *(Rangife tarandus platyrhynchus)* to direct provocation by snowmobiles. *Biological Conservation* 56:179-194.

U.S.F.W.S. 2006. Don Edwards National Wildlife Refuge Website. Retrieved November, 2008 from http://www.fws.gov/desfbay/

Van Parijs, S.M.; and P. J. Corkeron 2001. Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, Sousa chinensis. Journal of Marine Biology. Association of U.K. 81(3): 533-538.

Wiens, J.A. 1984. The place of long-term studies in ornithology. Auk 101:202-203.